NATIONAL ACADEMY OF SCIENCES
LIBRARY
DEC 19 1950
NATIONAL RESEARCH COUNCIL

National Research Council.
Bulletin

CONTENTS

1386
2 cow

Number 111
MANUAL FOR THE STUDY OF FOOD HABITS

Number 112
THE NUTRITIONAL IMPROVEMENT OF WHITE RICE

Number 113
Separately bound

Number 114
PROCEEDINGS OF THE PACIFIC SCIENCE CONFERENCE OF THE NATIONAL RESEARCH COUNCIL

Number 115
Separately bound

Number 116
INVESTIGATIONS OF HUMAN REQUIREMENTS FOR B-COMPLEX VITAMINS

Number 117
NUTRITION SURVEYS: THEIR TECHNIQUES AND VALUE

Number 118
DATA ON CHEMICALS FOR CERAMIC USE

Number 119
THE COMPOSITION OF MILKS

Q11
N292
nos. 111-119

BULLETIN
OF THE
NATIONAL RESEARCH COUNCIL
NUMBER 111   JANUARY 1945

MANUAL FOR THE STUDY OF FOOD HABITS

REPORT OF THE COMMITTEE ON FOOD HABITS

PUBLISHED BY THE NATIONAL RESEARCH COUNCIL
NATIONAL ACADEMY OF SCIENCES
WASHINGTON, D. C.

Announcement Concerning Publications

of the

National Research Council

The Proceedings of the National Academy of Sciences

is partly supported by the National Research Council which is represented officially on its Editorial Board and Executive Committee. It is open for the publication of papers to members of the National Research Council on the same terms as to members of the National Academy of Sciences.

Subscription rate for the *Proceedings* is $5 per year. Business address: Home Secretary, National Academy of Sciences, 2101 Constitution Ave., Washington 25, D. C.

The Bulletin of the National Research Council

presents monographs especially prepared by Committees of the Council or directories for general use in science compiled by the Council.

The *Bulletin* is published at irregular intervals. A discount of 20% from the list price of the *Bulletins* will be given to all who subscribe for the Series as issued, direct from the Publication Office. Numbers of the *Bulletin* are sold separately at prices based upon the cost of manufacture.

The Reprint and Circular Series of the National Research Council

renders available for purchase, at prices dependent upon the cost of manufacture, papers published or printed by or for the National Research Council. A discount of 20% from the list price will be given to all who subscribe for the Series as issued, direct from the Publication Office.

Orders for the *Bulletin* or the *Reprints and Circulars* of the National Research Council, accompanied by remittance, should be addressed: Publication Office, National Research Council, 2101 Constitution Ave., Washington 25, D. C.

A list of publications of the National Research Council with prices will be furnished upon request.

Digitized by Google

BULLETIN
OF THE
NATIONAL RESEARCH COUNCIL
NUMBER 111 JANUARY 1945

MANUAL FOR THE STUDY OF FOOD HABITS

National rese [illegible]

REPORT OF THE COMMITTEE ON FOOD HABITS

CARL E. GUTHE, *Chairman*
MARGARET MEAD, *Executive Secretary*

PUBLISHED BY THE NATIONAL RESEARCH COUNCIL
NATIONAL ACADEMY OF SCIENCES
WASHINGTON, D. C.

The Lord Baltimore Press
BALTIMORE, MD., U. S. A.

FOREWORD

Great headway has been made in recent years in building up scientific understanding of the food nutrients the body needs. In the collateral field of the study of food habits and of getting people to conform to scientific knowledge, only pioneering work has been done. Contributions are especially needed in: 1) the accumulation of sound basic data about food habits; and 2) the development of flexible methods suitable to solving emerging problems in this field.

Since November 1941, the Committee on Food Habits of the National Research Council has been gathering, coordinating, and appraising the available but scattered data in the field of food habits. At the same time it has encouraged additional and new approaches to research in this field. Utilizing the cultural approach, the Committee has investigated the factors which have brought about changes in food habits and the methods and procedures which have proved most effective in bringing dietary habits into conformity with dietary needs. Through its experience, certain definite principles have been arrived at. These can now profitably be offered to students of human behavior.

I feel that the Committee has made a very important contribution to scientific method in publishing this "Manual for the Study of Food Habits." I believe it is most timely and that it will be extremely valuable as a guide in extending research in food habits and in developing and broadening the interest in this subject.

M. L. Wilson, Chief
Nutrition Programs Branch
Office of Marketing Services
War Food Administration

PREFACE

This manual has been prepared as a contribution by the Committee on Food Habits of the National Research Council to the development of the field of food habits research. The main outlines of the problem and some account of the pilot studies were published in 1943 as *The Problem of Changing Food Habits* (National Research Council—Bulletin 108).

This present bulletin is directed toward a number of different types of students: those who wish to become specialists in the study of foodways of contemporary societies; those who wish to explore ways in which the science of nutrition can become an integral part of the food patterns of our society; those whose disciplinary responsibilities include a need for knowledge of and research in food habits, such as specialists in family life, nursery school education, standards of public welfare, practitioners in the field of mental hygiene and psychosomatic medicine, etc.; those responsible for large-scale social surveys in which the food habits of the populations studied will be one item covered; and scientists who wish to conduct their researches, primarily designed to further knowledge in their own chosen discipline, in some field where their results will at the same time be immediately useful to mankind. Exigencies of financing research, as well as a quickened social conscience, suggest that in a period of such rapid social change as the present, whenever pure research can be conducted in fields of immediate usefulness, the place of the research worker in society will become more significant.

Nutrition is a field in which enough scientific knowledge has been accumulated so that the well-being of mankind can be enormously enhanced by its application. The goal of better nutrition for the peoples of the world is one upon which nations and groups which differ in many other ways can agree and toward which they can work. The effort to reach this goal can be implemented only by bringing to bear all of our scientific knowledge, that of human cultures as well as of the human body, that of human attitudes toward food as well as of the chemistry of the food itself.

The plan of this manual was developed by the Committee on Food Habits and it has been executed under Committee direction by the staff. Dr. Margaret Mead, the Executive Secretary, is responsible for Sections I, II, III, and IV, and Dr. Patricia Woodward, Associate Executive Secretary, for Sections V and VI; the editorial work has been done by Miss Rose Kerrett, assisted by Miss Jessie Poesch.

Carl E. Guthe, *Chairman*
Committee on Food Habits
National Research Council

CONTENTS

PAGE

FOREWORD. M. L. Wilson 3
PREFACE. C. E. Guthe 5

PART I

INTRODUCTION

PART II

THE APPROACH OF THIS MANUAL

A. SUGGESTIONS FOR THE COLLECTION OF DATA 24
B. THE UNIT OF STUDY 25
C. DATA ARE BASES FOR ACTION 26
D. FORM OF THIS MANUAL 27

PART III

CONTEXT FOR THE COLLECTION OF DATA

A. OUTLINE OF CONTEXT 31
- 1. The Food Pattern 31
  - a. General description of the food pattern 31
  - b. Type of production 31
  - c. Type of preservation of foods 32
  - d. Type of distribution 33
  - e. Type of food preparation 33
  - f. Type of food consumption 35
  - g. Type of post-food consumption practices 36
- 2. Social Organization of Food 37
  - a. Division of labor 37
  - b. How food is patterned in relation to social status, caste, etc. 37
  - c. How food is patterned in relation to physical status, age, sex, pregnancy, illness, etc. 38
  - d. Social and ceremonial role of food 39
  - e. Food etiquette 40
- 3. Ideology of Food 40
  - a. General attitudes toward food 40
  - b. Basic phrasing in the United States 40
  - c. Regional and other variations 41
  - d. Nutritional theory influences social change 41
  - e. Cultural classification of foods 41
  - f. Symbolism of food 42
  - g. Food habits is a culturally limited concept 42

PAGE
4. Induction of the New Generation into the Food Pattern........ 42
  a. Developmental approach 42
  b. Infants' early experience with food..................... 42
  c. Elimination patterns affect food attitudes................. 43
  d. Parental attitudes 43
5. Material Culture and Technology of Food.................. 43
  a. Utensils and tools....................................... 43
  b. Type of building and room facilities used in food processing.. 44
  c. Realistic adaptation of methods to available cooking facilities. 44
  d. Material culture data necessary for comparison with other cultures 44
6. Food Pathology 44
  a. Factors influencing development of cults and food fads..... 44
  b. Cults and fads as modifying popular acceptance of nutrition concepts 45
  c. Psychosomatic manifestations and food habits............. 45
7. The Study of Stability and Change........................ 45
  a. Direction of change..................................... 45
  b. The study of stability.................................... 46
B. PLACING A PROBLEM WITHIN THE CULTURAL CONTEXT........... 47
  1. Intensive Studies 48
  2. The Development of Flexible Methods..................... 52

PART IV

SOME TECHNIQUES WHICH HAVE BEEN USED IN OBSERVATIONAL STUDIES OF FOOD HABITS

PART V

EXPERIMENTAL METHODS IN THE FIELD OF FOOD HABITS

A. UNDER WHAT CONDITIONS CAN A DIET BE SELECTED WHICH WILL MEET PHYSIOLOGICAL NEEDS ADEQUATELY?................... 61
B. UNDER WHAT CONDITIONS CAN ANIMALS SELECT THE MORE NUTRITIONAL FOOD MIXTURE FROM TWO OR MORE POSSIBLE CHOICES? 65
C. WHAT EFFECT DOES PREVIOUS EXPERIENCE HAVE ON THE SELECTION OF FOOD?.. 66
D. DO ANIMALS EXHIBIT PREFERENCES, AND, IF SO, WHAT ROLE DO THEY PLAY IN THE SELECTION OF FOOD?..................... 69
E. UNDER WHAT CIRCUMSTANCES CAN PREFERENCES BE CHANGED?.. 70
F. WHAT EFFECT DOES DEPRIVATION HAVE ON FEEDING BEHAVIOR?.. 72

PAGE
G. IN WHAT WAY DO SOCIAL AND EMOTIONAL CONDITIONS INFLUENCE BEHAVIOR TOWARD FOOD? 76
H. WHAT TYPE OF BEHAVIOR HAS BEEN USED TO STUDY INTENSITY OF HUNGER? 80
I. WHAT TECHNIQUES HAVE BEEN DEVELOPED TO STUDY THE FOOD AND TASTE PREFERENCES OF HUMAN BEINGS? 83
J. WHAT TECHNIQUES HAVE BEEN USED TO CHANGE FOOD CHOICES OF HUMAN BEINGS? 84
K. WHAT EFFECT DOES NUTRITIONAL STATUS HAVE ON LEARNING ABILITY AND PERFORMANCE? 90

PART VI

HOW TO FIND REFERENCES IN THE FIELD OF FOOD HABITS

PART VII

BIBLIOGRAPHY

A. ORIENTATION BIBLIOGRAPHY 101
B. BIBLIOGRAPHY 103
C. PARTIAL INDEX TO ALPHABETICAL BIBLIOGRAPHIES 132
  1. Some Regional Studies 132
  2. Studies Within the United States 133
  3. Theoretical Articles 134
  4. Psychosomatic Studies 134
  5. Studies of Children 134
  6. Methods 134
  7. Bibliographies 135
INDEX 137

PART I

INTRODUCTION

I. INTRODUCTION

The study of food habits is an applied science to which many different sciences have to contribute in order to find answers to the questions that come up continually in our attempts to improve the nutrition and living habits of the peoples of the world. As in any field of applied science, the solution of one problem only paves the way for another problem.

The varying conditions we have to deal with are, among others: 1) the traditional habits of a people in regard to what they eat and what they do not eat and how each generation of children learns to follow these traditional eating habits; 2) the existing states of food production, food processing, food distribution, including the extent to which any given food is available and accessible to each group in the population; 3) the existing state of the science of nutrition; 4) existing media for diffusing knowledge about nutrition; 5) existing medical practices which influence food habits; 6) existing conditions of and current changes in related environmental contexts such as housing, household equipment, transportation, etc.; 7) existing states and current trends in child training and education, including educational, preventive, and therapeutic measures, etc. Since all of these conditions are changing, some rapidly, some slowly, the interrelationships between them are also continuously changing.

As we are successful in educating people to include the findings of the science of nutrition in the way in which they plan meals and choose foods, this knowledge will alter their attitude toward eating, which will in turn create new conditions that will have to be studied and understood. As the problems change, new methods will have to be developed.

But although the problems will always be new and there will never be any solution which is final, even for a few years, two developments of permanent value can be expected to which research workers, students working on group projects, individuals working for degrees, and participants in larger group researches on different aspects of the contemporary scene can contribute: 1) the accumulation of a sound, consistently collected body of data about food habits; 2) the development of flexible methods suitable for solving emerging problems in this field.

The study of food habits may be defined as the study of the way in which individuals or groups of individuals, in response to social and cultural pressures, select, consume, and utilize portions of the available food supply. In common parlance, when we say an individual has "good food habits" we mean that he habitually consumes food in conformity with the standards of eating to which we subscribe. Such a statement may refer to the pattern of selection, to the range of selection, to a failure to reject any food, to the regularity and consistency with which certain foods are eaten, etc. "Bad food habits" may be applied to a failure to conform to certain standards of the same sort. At any given period in history, the standards which are invoked in the phrases "good" or "bad" will be a mixture of traditional usage, current nutritional knowledge, holdovers from past nutritional knowledge, and differences between one school of nutritional thought and another. Individuals may be approved or condemned for drinking a quart of milk a day, for eating more or less than the traditional number of meals, etc.

These compounds of tradition, morality, and science are terms also often applied to other peoples. The nutritionist reporting on the state of health of another country than his own may comment, "When I saw the way those people lived I realized how important food habits are." When he makes such a comment, he may still be thinking in terms of a large number of individuals who, because of lack of education, prefer to eat the "wrong foods." He may have made the further abstraction that a whole society may have a set of food habits which are traditional—sometimes called foodways—and shared by all members of that society, including not only the preference for certain foods, but a whole interrelated system of food production, preservation, distribution, and consumption.

He will then realize that changing the food habits of 3,000,000 people is not simply a question of "education" in the sense of introducing new standards through the schools, but that food habits are interwoven with the entire way of life of the people, and that points of leverage for change may be found in the schools, at state dinner parties, in the advertising pages of magazines, or in the methods of packaging processed foods. Conversely, he will realize that resistance to change may come unexpectedly from any part of the social system and defeat well-planned attempts at change.

A number of sciences, economics, sociology, anthropology, psychology, physiology, food biochemistry, soil chemistry, genetics, etc., contribute to our understanding of the way in which human beings, as organisms living within a social system, in a given physical environment, are nourished so that they survive at various levels of efficiency and reproduce themselves.

In the field of food habits we may focus upon the physical environment in terms of soil and water, the type of food grown there, and under what circumstances it will be possible to give adequate nourishment to a population within a given environmental range. We may study the existing diet through changes in that diet brought about by the use of fertilizer, by selective feeding of animals, or by genetic alteration of hereditary strains of plants and/or animals.[198] Under such an approach, the food habits of a given group of people in a given region are taken as the relatively inflexible factor, and efforts are made, in terms of the local economy, to modify the food so that the people, while preserving the same food habits, will be better nourished. The whole movement toward the enrichment, restoration, or reenforcement of common foods on a national or world-wide scale is of the same order. It treats the food habits of a population as inflexible, yet alters the composition of the foods which they habitually eat.

Or we may study a people's food habits in terms of their receptivity to new or unutilized foods which would supplement an insufficient diet.[478] Under this approach, which contemplates the alteration of the existing food pattern, it is necessary to study the existing food habits of a people and to devise ways of modifying them to include the foods necessary to supplement the diet.

Great Britain during World War II followed a combination of these two methods. Whenever possible, the habitual food pattern was preserved and supplements were added to the bread, or to the food when prepared in mass feeding operations. Only where it was necessary to increase the consumption of a food like carrots was great effort made to alter the behavior of the people rather than the constituents of the food. In the United States, with greater food margins and less food control, effort has been directed toward educating the people to make individual adjustments to changing food conditions. This emphasis on individual adjustment was congruent with the type of nutrition education approach which discovers what people's food habits are, brands some of them as wrong, and attempts to introduce new food habits by various means—moral suasion, threats, bribes, and social pressure; first at the conscious level, in the hope that after an individual has chosen, consciously and with a great moral effort, the right food for a certain length of time, he will then choose it automatically.

There has been a steady drift toward making such food choices easier, from the schools of thought which emphasized thinking in precise mathematical terms to the basic food chart introduced in the national nutrition movement in 1941, which gave a pattern within which wide individual latitude was possible.

The lack of reconciliation between the approaches to nutrition which emphasize altering the food and those which emphasize altering the habits of individual consumers has been in part due to the absence of a consistent body of data in regard to food habits, to the way in which children learn to eat or reject traditional foods, the way in which foods are categorized in any given society, the whole complicated set of beliefs and practices that regulate the way in which each human being, born with the needs common to all mammals, becomes a socialized individual, accepting and rejecting parts of his environment as edible and non-edible, at different times, for different purposes, in different situations.

The educators have not differentiated food habits from any other type of habit. If children could be taught to write by the Palmer method rather than in Spencerian style, then they could be taught to eat foods which contained vitamins instead of foods that did not. The food biochemists and the plant geneticists have taken the opposite course. Food was a material which their sciences taught them how to modify, while the motives and preferences of the human race remained inscrutable and arbitrary. So the biochemist wishes to use a knowledge of chemistry to alter not the habits, but the results of the habits, of human beings. A different twist is given to the whole question by the physiologist, who claims that if we could only have a human organism undistorted by educational pressures, it would be able to choose the correct nutrients—in a society where other human organisms, modified by the most advanced scientific knowledge, prepared the nutrients for them in pure form.[535] Meanwhile all three schools of thought are thrown back to the basic economic problem of the presence or absence of either the food itself or the purchasing power to obtain it. Those who focus on the economic problem point to the fact that people of a class or nation with the most food available are the best fed from a nutritional standpoint, and insist that it is not a matter of food habits, or even of composition of particular foods, certainly not one of attempting to train human organisms to make idiosyncratic physiological choices, but simply a matter of producing enough foods.

The field of food habits is the meeting ground of all these approaches. If the approach of the food biochemist is accepted, then a study of existing food habits is needed to indicate just which foods may be most profitably enriched and what steps must be taken to ensure that the enrichment does not misfire and build up attitudes of rejection (like that toward war bread), etc. If the approach of the agronomist and the geneticist is to be followed and existing elements in the diet are to be improved in this way, then such an approach includes an attempt to stabilize the food habits of the population whose food is being improved. If a careful study of the diet of a region showed that tomatoes were a highly favored food and might reasonably carry more of the load of providing certain vitamins than they do today, it would also be necessary to study the foodways of that population, and to take steps to prevent the diet's altering in some way so that after being improved, the consumption of tomatoes would not decrease in proportional importance.

The experiments of the physiologist in self-selection have to be integrated with existing habits of eating, the meal pattern, the way in which children are served or are permitted to serve themselves, cafeterias and à-la-carte service as contrasted to the home or restaurant meal that has been nutritionally balanced. If, through the efforts and the investigations of the economist, we know that the purchasing power of a given population or section of a population is to be very much increased, only a knowledge of their present food habits and the likely direction of alteration will make it possible to direct that increased purchasing power to maximum nutritional use. On the other hand, if there is to be a shortage of food or a shrinkage of purchasing power, a knowledge of the people's food habits is essential to make the necessary adjustments to preserve health and strength.

Knowledge of the foodways of a society, that is, of the food habits of the members of that society, is a meeting ground for all these attempts to apply modern science to the subject of human nutrition. Furthermore, it will continue to be so. There is no reason to believe that scientific nutrition will cease to be an ongoing process, changing with our increased scientific knowledge, with alterations in the form of society, in the methods of rearing children, in the incidence of disease and the emergence of new diseases, with new discoveries such as insulin, with changes in the hygiene of pregnancy and lactation, of growth, and of old age. Each new condition introduced by changing political organization, new scientific developments, new movements of peoples, or changes in the natural environment (soil erosion, new pests, changes in climate) will call for adjustments in the food habits of populations.

Appeals to motivations appropriate at one time and place will prove empty and dead at another time and place. A type of food habits which has meant a high order of adaptability in one sort of situation, e.g., eating what is set before you in the Army when the feeding has been planned by dietitians, may prove highly maladaptive in others, e.g., eating what is set before you in a boarding house run for profit in a period when all the protective foods can be obtained only at a high price. In a society which changes as rapidly as ours we will need continual new inventions in ways of educating a population to a degree of adaptability permitting mobility, conformity when conformity is desirable, and selectivity when selectivity is necessary. Continuous, ongoing research in the field of food habits is a necessity if we are to reap full social benefits from the findings of biochemistry and physiology, agronomy, and economics.

Furthermore, there is need for continued research in the field which takes into account existing purchasing power, existing nutritional knowledge, the existing food habits of the population. We also need historical perspective, because each generation of children is reared and influenced by the two preceding generations. Food habits are reflected not only inside the home.[204] They are reflected also in the attitudes of statesmen, politicians, publicists, educators, whom the scientists have to convince of the desirability of some new advance. An adequate study of food habits, year by year, decade by decade, will provide the background for the necessary alteration in our public procedures which influence food consumption as well as in the actual eating habits of the population. Whether food is regarded by public officials as something to sell or something to eat; whether the need for food of every human being is regarded as a natural and inalienable right or a legally restricted right dependent upon whether he "earns his living"; whether eating food is regarded as a duty to society, which is denied in a hunger strike, giving society a right to feed the hunger striker forcibly—all of these attitudes, which stem from the whole cultural attitude toward food, condition the acceptance of any scientific improvement in nutrition.

Food habits are studied so that we may know how well the practice of individuals, as patterned by their culture, or the type of individual experience permitted by the culture, assures adequate nutrition. Certain other considerations enter, such as the advisability of increase of stature of a whole population, or the level of fatigability at which it is desirable to maintain the part of a population doing heavy work. At one stage in our developing ethics of human welfare, it may be enough if the existing food habits preserve the population in the state of well-being in which they are found and have enough flexibility to permit them to meet inevitable change, such as that introduced by new food processing methods or imports of new foods. At a different stage of ethical sensitivity we may demand that the food habits of a population provide a basis for altering their food intake to supply not usual or present state of well-being, but an optimum state of health. We need not expect that the definition of optimum health will remain static, and so we may then require a higher degree of flexibility in food habits or, expressed another way, flexibility in institutional practices—such as number of meals, content of meals, methods of food preparation, etc.—to meet our new standards of what constitutes a good society. An applied science inevitably involves such changing values, and this should be explicitly recognized in the construction of research.[440]

We now come to the problem of how every study, however limited its scope or immediate its research aim, can also contribute to our growing knowledge of the food habits of the peoples of the world. Historically, there has been a great distinction between students of primitive and vanishing societies and students who worked within our own society. The first group, ethnologists and social historians recording vanishing social systems, were committed to making a large, rather regular set of observations, whatever the particular problem on which they worked. The assumption was: "You are the only person who will study these people at this period in their history. Later when another observer comes, the people will be changed. Perhaps no other observer will ever come. Therefore there is a body of relevant data which it is your obligation as a scientist to record regardless of the particular problem which you yourself wish to investigate."

So the student who was primarily interested in social organization was expected nevertheless to come back with a usable description of houses and canoes; the student of technology was expected to come back with a formal description of the kinship terms or the religious ritual. This obligation, which originally developed on the theory that there would be no other observer, later became embodied in anthropological theory, in the practice of placing any comment upon a society in the context of the whole tradition. So other anthropologists incorporated in their pattern of thinking an insistence upon completeness of data which had originally developed as a responsibility to history.

But when psychologists or sociologists have made studies within the framework of our familiar civilization they have been held to no such responsibility for making the data they used concrete enough to be relevant to the future researches of other scientists. They have been taught that they must take account of other studies which have used the same or related *methods* and of other studies which have sought to solve related *problems,* but that the actual data used in those other studies were irrelevant. Consequently a series of psychologists might study relationships between I. Q. and socio-economic class or I. Q. and race without being held responsible for systematically recording in each case the data which formed the background for their particular experiments. Social historians were judged by their fidelity to good past patterns rather than by their obligation to accumulate the same sort of data. Sociologists were expected to take cognizance of other work done in the same area, but were not required themselves to add data of the same order.

These tendencies were natural enough for several reasons. In the first place, the classical psychologist sometimes assumed that he was dealing with something called "human nature," and that the accidents of language, religious belief, class position, postural and gesture systems associated with any civilization might be ignored or at the most held constant. It is only very recently that it has been generally realized that, unless a psychological experiment is evaluated in terms of the culture within which it is planned and carried out, we miss many of its implications. Also, there was no sense of urgency or possible loss in the study which was made, such as of school children's attitudes toward different types of suggestion. No one thought it necessary to describe the schoolroom, how a fourth-grade teacher dressed, what was the usual ritual of recess or homework. These were familiar circumstances of everyday life which everyone *knew*; they were not on a par with the bull roarer or the wigwam of the savage which had to be meticulously described if they were to be understood at all. So we have masses of studies which have utilized current cultural data without recording it, without recognizing an obligation to observe it systematically.[42, 43]

This is a loss in two senses. The systematic observation of the factual data involved, for example, in a study of resistance to change, or amenability to suggestion, brings into focus the cultural setting within which the experiments are being made. A great number of facets of the problem and a great many new relationships emerge which would otherwise be missed. Secondly, we have no systematic mass of observation on such subjects as educational practices, food habits, health observances of different periods, regions, and classes, against which we can make systematic comparative observations in both time and space. When we come to any crisis in applying our scientific knowledge we have no mass of data upon which to fall back. Therefore it seems to be a definite responsibility of workers in fields like food habits, while they are exploring new problems and new methods, to build up a systematic mass of material which has been collected with impartiality and a fair degree of uniformity.

PART II

THE APPROACH OF THIS MANUAL

II. THE APPROACH OF THIS MANUAL

It is proposed in this manual to set up preliminary standards for the collection of basic data on food habits which any study, whether pursued from the standpoint of psychology, psychiatry, sociology, anthropology, or home economics, should be responsible for recording or systematically taking into account. Such a pattern as this can be added to as new classes of data emerge with the development of new hypotheses. By this process of addition to a consistent core one study can be related to another and no study is wasted. Furthermore, partially trained students and persons who are not primarily committed to research in human behavior can nevertheless make contributions of real importance in the collection of basic data.

To draw the conclusions which are needed today, to shape an educational program, to estimate the impact of some food shortage, some new food, some change in processing or distribution, to adapt a new medical discovery in the field of allergies, to expand the insights of mental hygiene into the feeding of the young child, or to estimate the importance of food and drink in a program of institutional care—for these and numberless other decisions which are now taken partly in the dark, we need data. We need data on the food habits of the American people, by class and age and sex, by region, by foreign nationality background, by degree of urban or rural residence, by occupation, by religion, by disease groups, by date of birth (for the food habits of people who are sixty today will differ from the food habits of those who become sixty in 1965), by amount of education, etc. There are several ways of getting such data. A giant survey could be conducted, costing many hundreds of thousands of dollars, the results of which, while systematic, would be out of date in a few years unless they were again built upon by later surveys. Or we can set up a pattern of research which includes as a matter of course the collection of these data, to the end that as our research grows, as our problems widen and our ability to solve them increases, so will the data which we need increase.

It is from the second point of view that this outline is presented. The student must judge how wide to throw his net. One method of narrowing the scope of data which he or she will attempt to collect will be to give cursory, main-heading attention to some subjects and detailed attention to others. The student of changes in food patterns which result from changes in equipment will need to describe the usual battery of pots and pans in great detail, but no student of other aspects of food habit problems should be absolved from describing the major utensils with which food is prepared among the people whose food habits he is studying. The student who is attempting to develop a method for evaluating the degree of overestimation or underestimation involved in a recall questionnaire on food eaten must know which foods are valued and which are undervalued, and how they fit into the total available list of foods. The student of the acceptance of a soy soup preparation in a school lunch program needs to know what the children ate before there was a school lunch, what "lunch" consists of in the community, where soup stands in the menu picture, and, in fact, what the meal pattern is for the group. He will also need to know what the service pattern is at home in order to evaluate accurately the children's acceptance or rejection of food individually served to them or set out in serving bowls, etc. He may not need to know what the seasonal variations in food are, but he would be wise to explore them to be sure they are irrelevant.

Experiments have been spoiled because the experimenter failed to investigate the constancy of supply of some food in the shops or the patterns of delivery at homes. The inclusion of routine background data of the sort recommended in this manual is insurance for students against spoiled experiments, besides providing for some addition to knowledge from each investigation.

A. Suggestions for the Collection of Data

The basic question. Scientific inquiry advances as the correct questions are asked, and whole periods of scientific research may be wasted in blind alleys if the scientist sets out to answer meaningless or wrongly posed questions. The application of science to research in food habits was in a blind alley position as long as the question which it was asked to answer was: HOW CAN WE CHANGE FOOD HABITS?, for this question was a static one. "How can we change food habits?" assumes that a given population has a fixed set of food habits, some of which are incorrect by our standards, and so we wish to change them to an equally fixed set of habits which will conform to the science of nutrition. What can the social scientist tell us, asked the nutritionists and educators, about how to stop the people from eating "A" habitually and make them eat "B" habitually?

Because this was not the definitive question, the answers were extraordinarily unrewarding, and scattered, unsystematic, and sporadic educational practices grew up. The question itself was out of step with modern science and changing technology. It was a holdover from the combination of morality and fixed practice which was the appropriate social behavior in a static rural society of hundreds of years ago. It ignored the facts that people no longer grow up and die where they are born, no longer follow the occupation of their parents, and no longer live as adults at the same level of technical development which existed when they were children. It was a question which derived from the assumption that our existing knowledge of nutrition was final and had the same authority as the religiously enforced morality of 17th century New England.

This question furthermore had no scientific base. It asked how to apply scientific knowledge without demanding the knowledge upon which that application could be based. Instead we must ask first: WHAT IS THE NATURE OF NUTRITIONAL BEHAVIOR? and expect to arrive at a formulation of nutritional behavior abstract enough to be applicable in all known varieties of human culture, with a definite dynamic understanding of the way in which the human organism takes on and uses culturally varying adaptations of the material environment. We can then alter the applied science question and ask: HOW CAN WE DEVELOP FOOD HABITS WHICH HAVE THE REQUISITE STABILITY AND FLEXIBILITY APPROPRIATE FOR GIVEN INDIVIDUALS IN A GIVEN SOCIETY AT A GIVEN TIME? This question has general validity and still is congruent with the climate of opinion of our time.

There was no way of answering the first question, because every answer had to be given locally, in terms of how to persuade a Georgia sharecropper to eat lean meat, or school children in Bridgeport to drink milk instead of coca cola. The local, immediate, time-and-space-bound end result desired had to be stated, as well as the disapproved condition from which the individuals were to be moved. Moreover, the question assumed that the applied scientist would operate upon a given identified group of individuals, that he would change persons directly, not that he would change a *system* of education. Yet any assumption which makes individuals, rather than a part of the social process, the object of social change tends toward the type of authoritarianism in education and political practice which is incompatible with democracy. HOW CAN WE CHANGE FOOD HABITS FROM EATING NATURAL FOOD TO ERSATZ FOODS IN PREPARATION FOR A WAR? would have been an appropriate question for the German Reich in 1936. HOW CAN WE DEVELOP FOOD HABITS WHICH ARE BOTH STABLE ENOUGH AND FLEXIBLE ENOUGH SO THAT OUR PEOPLE WILL BE ABLE TO ADJUST POSITIVELY AND MAINTAIN ADJUSTMENTS TO WHATEVER FOOD CONDITIONS EXIST? is a question which is consistent with the application of science in a democratic society. The specific answers to this question will be based on a knowledge of the culture, particularly of the state of food technology, of the way in which learning to eat is bound up with other types of learning, of the state of the science of nutrition at a given date, etc. The answer to the question can be given in a form which is dynamic, that focusses on developing social forms which promote and conserve adaptability within human beings rather than upon the alteration of concrete and specific habits in identified individuals.

B. THE UNIT OF STUDY

The unit of behavior for a study of food habits is not the food, expressed in terms of international units or specific nutrients, nor the human being exercising will power in making proper or improper choices, nor the amount of wages available per family per month. It is a *given human being* (whose whole behavior has been modified by his social experience) *consuming a given item of food* (the constitution of which has often been modified by human means) *at a given place* (where the availability and quality of the food will have been determined partly by local geographical conditions and partly by man-made improvements that will include the import of materials such as fertilizer or new types of seed, or the import of foodstuffs from another locality) *at a given period in history* (with the climatic and social conditions characteristic of that period).

If this unit be accepted as the suitable basis for research in the field of food habits, it follows that no statement is complete which does *not* include:

identification of the food eaten so that it is possible to state that food in terms of nutrients; identification of the human being eating the food so that it is possible to define him further in terms of the entire body of cultural practices which he now embodies in his behavior; identification of the place from which the food comes or, put another way, the position of the human being in a food production and distribution system; the exact time at which the act under analysis is taking place.

Although many additions to the study of food habits can be made by an adequate description of parts of this material, their usefulness and adequacy will be a function of the student's recognition of and allowance for the missing parts of the data. The student who is primarily interested in a state of vitamin deficiency may not have the techniques with which to make a study of the cultural attitudes toward food of Italian-Americans who are his subjects of study. If, however, he indicates the extent of the data on the subject and systematically recognizes his omissions, his results become a great deal more valuable.

It is furthermore important to realize that a human body is always involved in food habits and that fully to understand such habits the whole body, with its organized method of ingestion, digestion, and excretion, must be considered. The abstraction "food habits" must never be made so abstract that the actual constitution of the given food and the structure and function of the given human body are eliminated. Such unfruitful abstraction prevents an applied science from having those close and continuous relationships to human living which are essential to its actual application. Conceptionalized statements of populations with a given age and wage range consuming a given average of calories would, for instance, simply obscure all of the realities of differential impact of a food shortage. The device of always including identified human beings, members of an identified society, at an identified time eating identified foods, is an insurance against the development of the frequent gap between science and living, which studies like that of food habits aim to bridge.

C. Data Are Bases for Action

The study of food habits is important because action is contemplated in terms of the results. Action in a field like this can be taken only on the basis of concrete knowledge. We need to know what sections of the population have what type of food habits, so that steps can be taken either to preserve them or to change them, in part or altogether, in order that the population in question will make better use of the available food supply and so that the habits of utilizing food do not interfere with other types of valuable adaptive behavior. All principles involved in making a given change or conserving a given habit should be culturally based principles. Experience has shown that the attempt to think through problems of food habits in a cultural vacuum, in terms of abstract psychological principles, is unrewarding. All controlled social change is directed toward changing particular habits of a particular people at a particular place at a particular time.

Actual research in food habits will be conducted by a great many kinds of people, by graduate students, by field operatives in food programs, by students of opinion and attitude, by experimental psychologists who find the field of foodways and food habits a good setting for research. If the masses of data which are accumulated in these various types of research are conserved in the concrete form indicated above, then every investigation, however temporary its basic orientation, or however remotely theoretical its primary problem, may be expected to add some useful data to our growing knowledge of the food habits of the peoples of the world at different periods of history.

D. FORM OF THIS MANUAL

For purposes of discussion, studies of food habits will be divided into two types, *observational* and *experimental*. These two headings correspond roughly to the more usual methods of cultural anthropology and psychology. In observational studies the student does not attempt to alter the situation in any way and does attempt to allow systematically for his or her presence as an observer.[333] Data are accumulated by the systematic collection of observations made in terms of definite hypotheses and principles of organization. Problems are solved by finding real life situations in which the conditions necessary for solution exist. For example, if the student wishes to know the effect of extreme maternal indulgence upon children's attitudes toward food, he may find and study cultural groups in which the mother is indulgent, e.g., Italian, and compare them with groups in which food is used in a moral and disciplinary fashion, e.g., traditional New England. He takes existing situations and studies them.

Similarly, Dr. Hilde Bruch's study[93] of the family frame of obese children is an observational study, in which she made systematic observations upon the homes of a series of obese children and drew her conclusions from the regularities which she recognized within those home conditions as compared with other types of homes in the same society. Such observational studies are particularly useful in a field in which experimentation is very difficult because, unlike laboratory experiments in memory or learning, there is difficulty in managing the food closely, the subject is unable to consume food without altering his reaction to the next item of food, etc. Furthermore, because all experiments on human subjects are conducted upon human subjects who embody a highly patterned attitude toward food, observational studies of that pattern, in its historical, national, regional, familial, and individual aspects, are essential to an adequate evaluation of all experimental results. Results of experiments on Chinese or German subjects have to be interpreted against the whole cultural background of China or Germany before they become applicable to individuals from other cultures. So Part III, "Context for the Collection of Data," is at once a frame of reference for purely observational studies and an indication of the *type* of cultural consideration which any experimental study must take into account.

In the "Context for the Collection of Data" no attempt has been made to provide an exhaustive list of points which must be observed or questions which must be asked. The moment that a rigid list of headings is accepted for the observation of any ongoing cultural phenomena, the student's observation is so restricted and narrowed that the new insights which a more unpatterned and free observation would have provided are lost. The list of main headings is a list of aspects of the food pattern that cannot be ignored. They are essential for every complete study of foodways and any one of them may be germane to a laboratory study. For instance, studies in the degree of selectivity that human subjects exercise among different foods may have to be referred back to the method of production, the conditions of fertilizing, etc., under which those foods were grown, or the methods of processing and storage through which they have passed.

Beneath each main heading there are a series of annotations, designed to create an awareness in the student of the type of observation he will want to make, to focus his attention on observations relevant to food habits, to widen his estimate of what is relevant. To go further than this, to publish outlines, questionnaires, and schedules, would mean freezing a field of inquiry which must of necessity remain ever changing and flexible. While no two inquiries should use the same schedule or ask exactly the same questions, from every inquiry a body of exactly described and carefully recorded data should result, of such a nature that it can be usefully added to our growing store of knowledge.

PART III

CONTEXT FOR THE COLLECTION OF DATA

III. CONTEXT FOR THE COLLECTION OF DATA

A. Outline of Context

I. THE FOOD PATTERN

a. General Description of the Food Pattern.

Such a description will include the basic cereal (as among rice-eating peoples of the Orient), if the food pattern is one to which a cereal is central, or the basic protein core of the diet (as among the Eskimo), or the type of balanced pattern characteristic of our own diet. The principal foods which accompany and supplement the core foods and the characteristic beverages also constitute part of this basic pattern. Distribution of food consumption throughout the seasons and the unit of time within which the detailed food pattern repeats itself should be distinguished. The degree of uncertainty of any important element in the diet and the consequent limits of variation due to crop failure, conditions of employment, rhythm of employment, etc., should be stated.

Whenever it is available, a nutritional evaluation of a diet should be considered, combining with identifications of the actual foods eaten an evaluation of the nutrients received from each, deficiencies and sufficiencies in essential nutrients, and estimated caloric intake. Very often such estimates have not been published; they lie somewhere in a government committee report or as background for a board of health program. The field worker in food habits should unearth them if possible, because they will add enormously to the significance of the data ten and twenty years hence. Retrospective calculations, without specific data, on the essential nutrients in a diet which is no longer eaten, samples of which are no longer available, and methods of preparation for which have been lost, are likely to be far less accurate.

b. Type of Production.

Is the food supply the result of large-scale commercial agriculture within or without the country, locally grown for a local market, home-grown for home use? Are foods available only from one area where both plants and animals feed on the same soil, or is the food produced in many different regions or countries? Does the food come from one or several types of agricultural production, involving different scientific theories of agriculture, different types of fertilizer, types of plant and animal genetics, etc.?

Note: For the student of the foodways of a society, actually the whole of agricultural production would enter as a subject of study, but for the student of food habits, the type of production has far less detailed importance. For later evaluation of his material, it will be useful to know whether the vegetables which his subjects eat come from local poor soil or from some distant scientific truck farm, arriving after several days or weeks cold storage in transportation; whether the fruit they eat has been developed for size at the expense of vitamin content, etc. If taste factors enter into the study, it will be important to know, for example, whether fresh local vegetables constitute the subject's idea of what is a vegetable and whether all of the pork that a subject has ever eaten is locally grown and cured.

In the United States there is a distinct difference in the potential mobility of individuals reared upon a food supply which draws upon a wide variety of distant sources—our typical urban food supply—and individuals whose food habits are tied to locally grown, locally processed, regionally distinctive foods. If problems of interest and attitude to certain foods are involved, the relationship between the grower and his food is very different from the relationship of a buyer to food grown by someone else. In case of locally grown foods, individuals may identify enough with the prize local fruits and vegetables to be able to eat them as if they had grown them. Such problems as the inclusion of vegetables in men's diets involve considerations of this sort.

c. Type of Preservation of Foods.

Under this heading we have the whole gamut of food preservation from such traditional routine procedures as the milling of grain and the cold storage of meat to the most modern methods of processing fruits and vegetables, freezing, dehydrating, etc. In the United States we find all the variations from home-grown and home-ground meal in remote regions through home-grown grain ground at a local mill, flour from the national market purchased in sacks carrying a nationally known brand, flour always purchased in some further processed, e.g., self-raising form, flour never purchased except as bread and cake made in a local bakery or coming from a nationally known bakery. Obviously the individual's relationship to "bread" is exceedingly different under these different types of processing, varying as to whether he or members of his family play any active part at any stage in the processing. For a nutritional evaluation it is also important to know what type of processing lies behind a statement that an individual eats about "5 slices of bread a day," as collected on a routine food habits questionnaire.

Nor can it be assumed that the movement is all in one direction, away from locally produced, locally processed foods toward nationally processed food. Such institutions as the "food locker" have been spreading rapidly over the United States, but would not normally be included in any routine study of children's food habits in a school in a small Middle Western town. However, they are altering the degree of family planning and participation by making decisions as to what foods are to be processed and what foods are to be preserved in the family locker. The trend toward home gardens is another obvious example of the same tendency.

So for any study of food habits it will be necessary to know what type of food preservation is involved in the foods eaten, and what the individual's participation is in that preservation. There is no sharp line between food preservation and food preparation. When plums are made into jam they are obviously both preserved and prepared for eating, but in any given group of people distinctions will be found, as to whether the housewife's home canning is equated with her routine cooking or with a major agricultural activity.

d. *Type of Distribution.*

Is the food which comes on the table grown or exchanged or purchased? Is it part of the "furnish" allowed by a landlord to a sharecropper, or food which can be charged at the company store against a miner's or a millhand's wages? Is it bought in large quantities when the money for a cash crop comes in, as a barrel of flour or a side of bacon, or purchased in five- and ten-cent lots several times a day? Is the housewife's shopping of a type which differentiates the food, i.e., does she go to the farmers' market for fresh vegetables and dairy products, get her fish from a fish market and her dry staples from a chain store, or does she buy all of her food from one general store with very little sense of shopping for quality or price? Are certain foods like milk and bread delivered, so that the pattern of diet is affected by the greater availability of one brand or type? Does the housewife shop by the week and vary her meals against a well-filled larder, or does she improvise each meal? Who shops—housewife, children, husband? Is shopping done by quality, price, or brand? Is the food bought packaged or loose, so that more sorting has to be done in the home?

All of these variations make an enormous difference in the formation of food habits. If a given meal comes from a large supply of food and the children know that "that barrel of apples is mighty sour," or "that side of bacon is too fat," this engenders a very dissimilar type of acceptance from the imperious relationship to the "butcher who sent me those ridiculous lamb chops." The pressure upon individuals to eat a given dish or meal, the terms on which they are willing to do so, the attitude toward monotony, the insistence upon standardization of product—all these will vary with the way, the form, and the time scale in which food enters the home.

The nutritional value of the food eaten will also vary as to where the point of control lies. In purchasing a can of string beans, the housewife can only choose between brands which themselves are based upon standards of beauty rather than nutrition. Her maximum wise choice must be whether to have a canned or a frozen or a fresh vegetable. If, however, she shops in a market, she can choose among fresh vegetables as to their degree of freshness. If she has only canned beans left in her jar closet, the family will have to eat beans or no vegetable at all. So in any study of channels by which food reaches the table and who controls these channels, knowledge of distribution is essential.

e. *Type of Food Preparation.*

The amount of preparation which goes on inside and outside the home is the first major variable to consider here. Where food is home-grown and home-processed, methods of cooking and serving constitute the end of a self-contained sequence, are closely related to the steps that go before, and are difficult to alter except in relation to that sequence. For example, the length of time that a woman on a farm cooks her vegetables may be related to the time at which she gathers her vegetables from the garden. When she is an urban woman who shops, it may be related to the time of day at which she likes to shop. If she orders foods from her home over the telephone, it may be a function of the delivery system or of her favorite radio program, completely disconnected from any other process related to food.

So the first statement to be made would be whether the food is bought already prepared, as from a delicatessen, supplemented with canned and frozen foods, and merely served in the home; whether there is a certain amount of routine cooking on the top of the stove, as in defense housing or crowded urban living with single electric plate cooking; or whether the housewife not only fries and boils, but also roasts and bakes and prepares foods which involve a long time sequence and a series of elaborate steps. Extremes of this sort can be found between the habitual diet of the British working class—bread, margarine, tea, fish and chips, with a joint on Sundays—in which a minimum of actual cooking is involved, as compared with traditional Czech cooking still found among Americans of Czech descent.

Where a food habit questionnaire or check list might contain the word *cake,* with allowances for frequency and preference, it will make all the difference in the world whether that cake is bought in cellophane from the general store, purchased from a fancy bakery, baked by the housewife from her one cake recipe, or whether it represents to the subject a richly patterned variety of different types of cakes for various seasons and ceremonies. In any cross-section of Americans, all of these types would be represented, and to sum it up under "65 per cent of the subjects ate cake more than once a week," is an arid statement, both culturally and nutritionally.

For any study of food habits, something about food preparation in the home is necessary, and if the study is directed toward any final nutritional assay of intake, detailed knowledge is necessary if any estimate is to be made of the nutrition derived from the food. The most meticulous food consumption study which weighed the food before it was eaten and weighed the waste, but did not take into account the method of cooking, temperature, length of time, disposal of fluids, etc., would give a distorted food picture.

If a change in dietary practice is to be made by changing the *method* of food preparation, then a great deal must be known about it, including the housewife's schedule, the way in which food preparation tasks are related to her other tasks, care of children, work on the farm, gainful employment outside the home, participation of other members of the family, extent to which her own sense of prestige and adequacy are tied up in her cooking abilities, clash of ethnic food patterns within the home (as when the husband comes from one foreign background group, the wife from another), class typing of various types of activities, e.g., in certain sections of society a "lady" may bake cake or make jams, but perhaps not cook a meal or bake bread.

f. *Type of Food Consumption.*

In a sense, the whole study of food habits is a study of food consumption. But it is necessary to differentiate from the type of food consumption meant here two types of studies which fall into different technical fields. If it is necessary to know just how much of each food an individual or a household actually purchases and consumes, this can be done only by very elaborate quantitative studies which include accounting for all the food on the shelves at a given period. Methods like those used by the Bureau of Human Nutrition and Home Economics [502, 593, 595, 607] provide such an exact study of what is used by households of different economic level and region. More detailed nutritional surveys that seek to connect what is actually eaten with the nutritional status of individuals or groups must include, in addition to assays of the food itself, even more detailed measurements of the exact amount actually eaten by the individual. These can usually be obtained only by weighing the food before it is eaten and weighing the amount not actually consumed.[410, 605]

Both types of quantitative food studies, those with a food economics slant and those with a nutritional survey slant, are outside the field of food habits proper, although each type would be greatly illuminated by a parallel study of the pattern of food habits of the groups studied. The food economics study can show what people spend on food, the exact quantity of food they buy, and what they eat for each meal, if provision for checking the consumption at each meal is included in the research. The nutritional status type of check on food actually eaten can also say what an individual or a group of individuals eats for each meal. A food habits study would add what their idea of a meal is, whether they are eating what they think is appropriate and suitable, where and under what conditions and in terms of what appeals they would be willing to change that meal, how rigid or how flexible the whole pattern is, etc.

Under type of consumption, then, would be included the whole qualitative detail of the food pattern, what foods are eaten, at what seasons, for what meals, under what circumstances, in what combinations. For urban communities, the pattern of consumption is becoming increasingly independent of season as canned and frozen foods replace fresh foods. In higher income groups, only the survival of earlier food preservation practices gives a seasonal patterning to such foods as oysters. Lower income groups are to some extent still dependent upon season, since it determines price.

While seasonal patterning of food is virtually disappearing in cities, meal patterning remains fairly rigid for all except very low income urban and rural groups. Breakfast is usually highly differentiated from the other two meals, and food is thought of as "food for breakfast" or "not food for breakfast" to such an extent that failure to take meal patterns into account would defeat any nutritional program. Odd-shift workers who fail to eat a meal labeled as "breakfast" simply lose out on certain nutrients.[218] Wherever possible it is important to record the *ideal* for each meal and the usual practice, as well as, where these ideas are clear, the foods which are ***not*** appropriate for a given meal. For instance, young Americans who lack a New England tradition may reject pie for breakfast. Eggs and bacon may be regarded as appropriate; cereals may be regarded as only breakfast foods.

In studying meal patterns it is not sufficient to give a series of menus, but necessary to find out what the divisions are in the minds of the people who eat those foods, what is meant by a "course," a "main dish," "dessert," "beverage." Is milk for small children an analogue of coffee or of water, or is it a food? What is the position of orange juice and tomato juice, and when are they analogues of an orange, a cocktail, or a plate of oysters? What is meant by the category "spread," in which various types of food, sweet, sour, tart, sharp, bland, nutritionally different, are all classified as a "spread" for bread? What foods constitute a "snack" rather than a meal, a "lunch" to be carried?

Thus there are three distinct approaches to the study of food consumption: 1) the study of the food consumed, by whom, when, and under what circumstances, which requires the techniques of the "food economist"; 2) the study of the exact nutritional quality of the food consumed and the effect upon the person consuming it, which requires the special techniques of the "nutritional survey," including biochemical assays of the food eaten, the effect of the methods of preparation used, measurement of the portions consumed, and clinical studies of the individuals; and 3) the study of the pattern of food consumption, of the ideas and concepts which the consumer has about the use of food, which is the problem of the student of food habits.

g. Type of Post-Food Consumption Practices.

The disposal of waste is a topic that, except in wartime, has been regarded as more the function of public health than of nutrition. Yet if the food biochemist discovers that a given method of boiling a vegetable means that certain nutrients escape into the boiling water and can be conserved only by using that water, then the housewife is urged not to waste the water but to use it. Thus the borderline between what is a leftover, to be eaten at a less important meal, and what is waste—something to be given to those who are considered members of a lower order, servants, members of another race, pets, domestic animals, farm animals, or to be discarded altogether and buried, burned, or carried away by the garbage man—is a shifting line, depending upon custom, scarcity, and the state of nutritional knowledge. But unless it is known how a given group of people regard an article or a type of food—cold boiled potatoes, the ham bone, skim milk, beet tops, vegetable water—when it is classified as no longer fit for the main meal, or main table, or chief human inhabitant of the household, it is very difficult to persuade people to eat these hitherto rejected foods.

Human attitudes toward leftover foods are very different if the foods are mixed up into a mash for chickens or pigs, fed to the dog in a corner of the kitchen, dumped into a large, never-cleaned unsavory garbage pail, or deposited in a paper bag and thrown immediately down an incinerator shaft. Very different amounts of rigidity in both the utilization of previously discarded items of food and attitudes toward new and unfamiliar foods may be expected, dependent upon the type of dishwashing and garbage disposal which individuals experience in the home. Greasy, dirty dishes left to accumulate in a sink build up attitudes toward food itself. Willingness to purchase fresh vegetables which result in a large amount of garbage may be determined by the type of garbage disposal available. Unwillingness to wash dishes after a fish meal may be responsible for rejection of fish in the diet.

Most importantly, leftovers tend to become associated with other forms of discarded food. Husbands refuse to eat them; people of low economic status give up eating leftovers as soon as they make more money; people reject dishes in mass feeding situations which look as if they had been made from leftovers; and the whole pattern of food acceptance and rejection hinges upon methods of waste disposal in the home.

A minimum statement would include current methods of garbage disposal, whether servants took leftover food home, whether chickens were fed scraps from the table, and general attitudes toward leftovers, as appropriate or inappropriate for men's lunchboxes, children's lunchboxes, the noon or evening meal, etc.

2. SOCIAL ORGANIZATION OF FOOD

In any study of food habits, some minimum statement of the way in which the production, preservation, and distribution of food are organized is necessary as a background.

a. Division of Labor.

Depending upon the type of subjects or population, it will be necessary to know something of the division of labor between the home and outside agencies, between husband and wife, between employers and servants, between parents and children. In an agricultural community, this will involve division of labor in regard to production. If the food habits of an urban industrial population, without gardens or lockers, are being investigated, it will apply only to division of labor in planning, shopping, preparing food, and disposing of waste. Unless it is known whose is a given task, it is very difficult to influence or change the way in which the task is done. Who does a job also gives clues as to the relative prestige of different jobs in connection with food, whom to educate, and where.

b. How Food Is Patterned in Relation to Social Status, Caste, etc.

In almost every culture only part of the available food supply is actually used, and that part is also differentiated; some foods are rarer, finer, more delicate, more desirable, more expensive than others. Wherever the society makes social distinctions between individuals or groups of individuals, there is a tendency for these distinctions to express themselves in foods eaten, or believed to be eaten, by other groups. Immigrant groups in the United States are frequently characterized in terms of some unfamiliar food on which they are reputed to live. Certain foods, especially foods which are inexpensive and adequate substitutes for more expensive foods, may become associated with low social status and so rejected, particularly by the members of the next higher social group. White bread, plentiful white sugar, and meat every day were symbols of high social status in Europe and became increasingly accessible to European immigrants in this country. Their position in the social scale accounts for some of the changes from European food habits in this country and also explains the stubbornness with which many people cling to white bread.

In each region, and in the large cities on an almost national scale, there are foods which are regarded as appropriate for one's own class, and others for other classes. While most or all of the individuals of a given group may fail to obtain the socially appropriate food, they may nevertheless go to great lengths to conceal this fact. Any study of food habits should take into account this class-typing of foods, which includes, of course, not only the food itself, but methods of purchasing—"I've dealt with Mr. Jones for years and he knows what kind of roast we like"—and methods of preparing food and ways in which it is served. Through the magazines, the moving pictures, the radio, and the schools, children of deviant groups learn what are the approved foods and meal arrangements of food, and often consistently falsify records of what is eaten in their own homes in order to conform to the nationally approved picture.

Attempts to introduce foods or methods of preparation which have not been incorporated in the national or regional ideal picture will often meet only with resistance. In every case where a study is to be made, this picture and its local variants, as well as actual practice, must be known.

c. How Food Is Patterned in Relation to Physical Status, Age, Sex, Pregnancy, Illness, etc.

Almost every society has recognized that because of the close connection between food and the body, different states of the body might be appropriately symbolized and controlled by food. Particular foods for infants—taboos on all food except milk, special preparing by chewing or pounding, or special selection of foods for infants—are found almost everywhere. Today beliefs about infant feeding are a conglomerate of folklore and variant pediatric practice, and a point of great conflict between generations, especially if the grandparents come from another society. If certain foods are regarded as baby foods, or female foods, or convalescent foods, this labels them for the members of the society who are not in those categories. So soft foods become classified as "slop," milk as baby food in many groups, salads as feminine food suitable for the female who is reducing.

Such practices as a taboo on eating large strawberries, which will "mark" the child, and a pattern of eating a double chocolate nut sundae after being weighed in the prenatal consultation room become increasingly important as more is learned of the importance of nutrition during pregnancy.[213, 214] Dietary standards for the sick and convalescent become more and more a matter of professional concern of physicians and dietitians, but the way in which those who are not ill view these precautions remains a determinant of their acceptance of new foods or foods not eaten formerly.

Every increase of knowledge in scientific nutrition will serve to differentiate the food for different bodily states more accurately and at the same time increase the conflict between classifications which are based on folklore and those based on science. Taboos on the mother's eating meat after parturition still exist in this country and seriously reduce the new mother's protein intake. Nutrition for the aged runs directly up against the resistance of the aged to being classed with infants in regard to certain types of food intake.

How food is apportioned within the community or within the family may also be very important whenever a near-subsistence level is reached. Studies in Great Britain and Canada and material from first generation European families in the United States show how uneven is the division of food between the head of the house, the wife, and the children. In some cultural groups the eldest son or the favorite child or the invalid member will be given far more than his share. During periods of scarcity, as in the United States in 1942-44, shopkeepers will favor customers who have been the most generous buyers, and so different types of food, sometimes of high nutritional significance, will be unevenly distributed throughout the community. Relationships between wholesalers and retailers will also pattern themselves on earlier relationships, and certain areas, such as new settlements or poorer neighborhoods, suffer. Such differences as these tend to be obscured by the type of economic study which deals in the amount of food available in a large area or the per capita consumption of food.

d. Social and Ceremonial Role of Food.

Whenever food becomes part of the celebration of a holiday, the observance of a religious feast, the mark of some life crisis such as a funeral feast, the setting for some business transaction or for the maintenance of social position, a great many reenforcing factors enter in to make certain foods valued and others disapproved or reserved for special occasions. Resistance to a whole series of suggested dietary changes may be traced back to fear that the special Sunday dish or Christmas dish will also disappear, and very often, notably in mass feeding situations such as in schools or camps, the token inclusion of some one highly valued dish will remove objections to a great number of other changes. The familiar diet is often symbolized by the feast dish. The social importance of an occasion demands celery and olives on the table. Whether or not certain foods are "company foods" varies from class to class and from region to region.

Reactions of people not only to nutrition education, but also to price changes, government controls such as rationing, action of the commissariat on a ship or in the army, may be heavily conditioned by the presence or absence of one ceremonial dish, whether it be a birthday cake, turkey for Thanksgiving Day, ice cream on Sunday, or fish on Friday. The more conspicuous relationships between religion and food, such as the dietary laws of orthodox Jewry or the Catholics' fast during Lent, are usually taken into account, but students should realize that in the less prominently patterned life of the United States there are also a great variety of ways in which food is woven into our social ceremonial, and these complicate any sort of group cooking, mass feeding, and naïve nutrition education.

e. Food Etiquette.

In the course of learning to eat, heavy sanctions are used to make children reject some foods and accept others, eat in certain ways and refrain from eating in other ways. A background of disgust and sensitivity is built up while the child is being taught to feel that eating with his knife, or blowing his soup, or sticking his personal spoon into the serving dish are major offenses. Out of this stringent training, which occurs in some form in every society, usually increasing in intricacy but not necessarily in emotional strength with increased social status, there develops a great deal of rigidity in table etiquette.

Food may be rejected if it is not presented in the habitual container or with the habitual gesture.[227] New foods may become associated with old foods by the way in which they are served. Changes in ways of eating may be effected by changing the etiquette; introduction of a blessing may result in a family, who always ate standing, sitting down around a table; getting the housewife to sit down and serve the vegetables instead of waiting upon the menfolk may mean that she gets a better share of the meal; taboos on little children coming to the table may mean better or worse food for them. Adults may be unable to eat in strange situations in which a different type of table covering or cutlery or dishes is used, unable to drink coffee from a cup without a saucer.

So the whole gamut of what we think of as "table manners"—including when and where a table is set, how it is set, the way and order in which food is served, by whom, to whom, in what type of dish or container, how it is eaten, with what sounds and gestures, etc.—is important in understanding local food habits or attempting to change them.

3. IDEOLOGY OF FOOD

a. General Attitudes toward Food.

Under this heading we might include the whole patterning of food by time of day, season of year, religious and patriotic events, social status and caste, which have been dealt with elsewhere. After these various topics have been covered, there will remain a series of general abstractions which can be made about the culture of any group of people, or the personal version of that culture expressed by any individual, in their general attitudes about food. Such phrases as "Man does not live by bread alone," "An army marches on its stomach," "Bread and circuses," "A well-nourished nation is a contented nation," all express general cultural attitudes toward food.

b. Basic Phrasing in the United States.

In simpler societies and during periods of war and scarcity or economic depression, food may become a major consideration around which virtually everything else hinges, but in our own society we do not assume that food anxiety should ever legitimately occur. We do not think of the problem as *how to get food*, but as a question of *what people ought to eat* for health, growth, and efficiency, and of how much indulgence they may permit themselves in eating foods which are pleasant but which they ought not to eat if they take proper care of themselves. This attitude underlies our nationally expressed attitudes toward food, but there are many local and regional versions and variations expressed in attitudes carried over from Europe.

c. Regional and Other Variations.

In the Southeast, personal liking for food and the food's agreeing with the individual is more strongly emphasized. In California, health is a major goal rather than the duty which it is felt to be in other parts of the United States. Among workers in heavy industries certain quantities of food are felt to be their due as a given type of workers, while for women clerical workers who lack any social life food may become the only pleasure which they recognize. Food may be a subject of absorbing interest, as to some Europeans, or a subject of boredom and acceptance. Pleasure and good nutrition may be seen as opposed or as combined in an individual's food behavior. Where there is a strong cleavage between the acceptance of official ideology about food and actual preference, there is less guarantee of a well-nourished population than where pleasure and correct eating have been combined. Such a situation was found in a projective test given to Cedar Rapids children,[342] where they put such foods as green vegetables and fruit juices under the heading "Swell," and candy, cake, ice cream, and hot dogs under the heading "Terrible."

d. Nutritional Theory Influences Social Change.

With the rapid diffusion of knowledge of scientific nutrition, this knowledge and attitudes toward nutritional theory itself and the official practitioners—nutritionists, dietitians—have become part of the ideology of food and determining factors in social change.

e. Cultural Classification of Foods.

Another aspect of the ideology of food is the way in which edible materials are classified as inedible, edible by animals, edible by human beings but not by own kind of human being, edible by human beings such as self, and finally edible by self. These classifications are further reenforced by various sorts of attitudes—that materials which are not eaten are defiling, wicked to eat, coarsening, would alter one's social status, etc. A second type of category is found in such culturally dictated classifications (sometimes informed by a little physiological knowledge) as foods that are "heavy" and "light," foods which provide strength, influence the course of pregnancy, etc. Finally, all types of local classifications into essential and luxury foods, primary and secondary foods, old and new foods, farm and store foods, etc., may be important in understanding the food behavior of a given group of people.

f. Symbolism of Food.

In most cultures food is also used symbolically, either actually as in communion meals or in the figures and images of speech. Such phrases as "the wine of life," "the blood of the grape," establish cross-references to wine as blood and set up a multiple set of reenforcements of the attitudes toward wine. There is an Italian saying, "As good as bread," and bread recurs as a symbol in a variety of social and religious contexts.

g. "Food Habits" Is a Culturally Limited Concept.

The concept of "food habits" as used by practitioners in our society is not a scientific abstraction alone, but contains within it our cultural attitude toward food and implies 1) that there are two kinds of food habits, good and bad; 2) that each individual must make a moral effort to decrease his bad habits and increase his good, i.e., nutritionally acceptable, habits; and 3) that good dietary practices must be reestablished against odds in each generation.[401] Thus every culture will be found to have its own interpretation of the disciplines of medicine and nutrition, and in making any study of food habits it is necessary to know what these interpretations are.

4. INDUCTION OF THE NEW GENERATION INTO THE FOOD PATTERN

a. Developmental Approach.

A food pattern, that is, the food habits of a group of people, seen systematically as part of their social tradition, may be studied by the observance of adult behavior, combined with introspective accounts of childhood memories and the expression of attitudes toward the care and feeding of children. But another and especially useful dimension is provided by a study of the way in which each new organism, born without any system of habits, is reared so that as an adult he will approach food in a definite way, become hungry at definite times, for particular combinations of food, have definite attitudes toward food and those who give it to him or withhold it from him, and rely for his continued healthy existence upon this culturally patterned set of habits. Biological hunger is transformed into culturally patterned appetite.

*b. Infants' Early Experience with Food.**

What is the infant's initial experience of eating? Is it nursed, fed lactose, starved until the mother's milk has come, put on a formula at once? Is it breast-fed and weaned to a bottle, breast-fed and weaned to a cup, weaned suddenly or gradually, and how? Is it supplementary-fed, and with what foods? Is the supplemental feeding—additions to a milk base to complete a formula, orange juice, cod liver oil, etc.—regarded as "food" or as "medicine"? Is the infant fed indulgently or with routine, emotionless practicality?

Is the child given any substitute for the nipple, such as a rubber pacifier or a bit of cloth soaked in sugar? What is the attitude toward thumb sucking?

---

* See Partial Index to Alphabetical Bibliographies, No. 5, Studies of Children, for references to studies focussed on children particularly.

Is the child always fed in the same way, by the same person, at the same times? In what form are foods other than milk introduced, mashed, chopped, etc.? How is teething patterned—is the child given hard food or some hard non-food object on which to cut its teeth? How early are table manners insisted upon? What sanctions are introduced to keep the child from eating too much, to train the child to eat certain foods? Are certain foods devalued by bribing the child to eat them and other foods enhanced in value by being used as rewards and presents?

c. Elimination Patterns Affect Food Attitudes.

What are the cultural practices in regard to elimination? For the developing child intake and excretion must be organized into a systematic relationship with food and the world, and later attitudes toward food, especially food rejections, narrow reliance on particular foods, food faddisms, and gastro-intestinal disorders are traceable to the way in which the growing organism is patterned in both intake and elimination, not merely in intake.

d. Parental Attitudes.

How is the process of growing up related to food eaten in such statements as: "You're not old enough to eat that," "He's old enough now to drink milk or not as he likes," "My children are all grown so now we eat what we like"? What is the role of mother, father, nurse, grandparent, brother or sister, teacher, schoolmate, impersonal authority, in food habit learning?[242] Do parents alter their food habits when they are rearing young children, and is this phrased as a temporary deprivation? Is eating a pleasurable or a distressing experience? Are feeding problems frequent?

A careful outline of the whole process of lactation, weaning, learning to eat and to control eliminations, learning to eat at the right time, in the right place, in the right way, for the right reasons, will provide the background for a much greater understanding of the psychodynamics of food habits in members of any society.

5. MATERIAL CULTURE AND TECHNOLOGY OF FOOD

a. Utensils and Tools.

Every phase of the food process, from production through post-consumption practices, has its utensils and tools, which not only implement that stage in production but serve also to standardize and perpetuate that type of food behavior. In any study of food habits it is necessary to judge what part of the system of tools and utensils is actually involved in the situation. These may be found to be merely the utensils of eating and the way in which knife and fork and spoon, cup and plate, have been established in the eating habits of the subjects being studied. If the study includes methods of preparing food, then at once stove and pot become of primary importance.[184]

b. Type of Building and Room Facilities Used in Food Processing.

No adequate description of the food pattern of a group of people can be given without a description of the kitchen and the buildings concerned with food processing and storage, the utensils, the form of heat, the time schedule of operations within this material framework, etc.

c. Realistic Adaptation of Methods to Available Cooking Facilities.

Very often methods learned in special classes, in schools, or advocated over the radio or in newspapers are totally incompatible with the actual physical conditions under which food is prepared and eaten in a given home. Dishes which require three saucepans to prepare are recommended to women who have only a frying pan, roasting to those who cook on one electric plate, quantity buying to those who have one open shelf for dishes and food, large cuts of meat to those who either do not have or cannot afford to use an icebox, elaborate lunches to those who carry their lunches in paper bags to meet plant gate inspection rules or local fashion in high school lunches.

d. Material Culture Data Necessary for Comparison with Other Cultures.

Food habits always have a material culture aspect—a tool, a utensil, a container, a place in which the given food is prepared, dispensed, or eaten. All descriptions of this material culture should be accurate enough to be permanently valuable and useful in making comparisons with other cultures, and the student should not rely upon trade and brand names, such as "Sunlight Range" or "Marvelous Roaster," as a method of identification.

6. FOOD PATHOLOGY

There are two major types of food pathology which are important enough to deserve consideration in any study of food habits: 1) the type of deviant social attitude which is expressed in cults and fads, and 2) the type of systematic miscarriage of character formation which results in certain definite forms of psychosomatic disorder centering about gastrointestinal processes.

a. Factors Influencing Development of Cults and Food Fads.

Cults and food fads highlight the culture pattern. A cult like vegetarianism is a reflection of the terms in which we eat certain types of meat and not others, often including within the "unthinkable to eat" category domestic pets or animals closely associated with man. Also the close association of meat with masculinity, reproductive energy, and aggression provides a matrix from which reactions against flesh eating can develop. Excessive emphasis upon habit training in childhood or the invocation of unpleasant looking or tasting substances in weaning furnish a background for the type of diet which rigidly separates one type of food from another. Statements of the findings of science as a great mystery, coming from the House of Magic, provide the perfect setting for the magical use of diet to correct every imaginary ill. The use of food as a sanction in moral upbringing—"If you don't obey mother, you can't have any dessert"—makes a likely background for the search for an authoritarian and omnipotent leader in the head of a food cult.

b. Cults and Fads as Modifying Popular Acceptance of Nutrition Concepts.

In actual practice the presence of cults and fads, themselves distortions and overstatements of the existing pattern, may also either impede or facilitate change. Scientists may hesitate to entrust more responsibility to uninformed teachers; the acceptance of food fads by personalities of high popular interest may increase the average man's interest in nutrition. A concept of vegetarianism as a pallid and flesh-denying doctrine may decrease male acceptance of more vegetables, etc.

c. Psychosomatic Manifestations and Food Habits.

Psychosomatic aspects constitute a field in themselves. The student of food habits may obtain much insight from a consideration of the more elaborately delineated forms, such as anorexia nervosa, or material on the wide prevalence of gastric ulcer at this present stage in our civilization. Exploration of the character structure of individuals suffering from specific psychosomatic disorders,[179] if correlated with the existing food pattern in the society, provides valuable clues to the psychodynamics of food attitudes.[399, 405]

Any study of historical change in food habits should include, if possible, the changing disease picture, with a recognition that changes in the incidence of peptic ulcer will be relevant at a different level from changes in diseases which can be attributed to vitamin or mineral deficiencies in the diet of the period.[417]

Deutsch's [179] studies of asthma illustrate the way in which a piece of social behavior, mothers' preoccupation with making children eat the right, i.e., nutritionally dictated, food, coinciding with whooping cough or bronchitis, may lay the foundation for asthma. Studies of allergies have to be correlated with the current practice in early child feeding, immunization, etc. Then too, alcoholism and drug addiction throw light upon and are undoubtedly systematically related to the eating and drinking practices of a society.

Where the results of psychosomatic studies supply valuable insight for the student of food habits, conversely, psychosomatic studies to be fully interpreted must be informed by a knowledge of the culture within which their selected groups of subjects have been reared.

7. THE STUDY OF STABILITY AND CHANGE

a. Direction of Change.

Because the study of food habits is a field of applied science, in which our primary interest is the progressive adjustment of traditional dietary practices to the changing findings of nutrition and medicine, and the continually changing patterns of living and making a living in modern societies, the direction and nature of change in any area under observation should be one important dimension. Do the people include historical perspective in viewing their own food habits—"Here in the United States we eat meat every day"? Is there actual knowledge of earlier dietary practices, their advantages and disadvantages, and how are these expressed? Are there changes which have taken place in which traditional behavior which was formerly desirable has served to establish or perpetuate nutritionally undesirable behavior; e.g., substitution of synthetic orange preparations deficient in vitamin C for oranges for infants after mothers have incorporated the need for orange juice into their pattern of infant feeding? What are the changes observed in response to new foods, new methods of food preparation, new habits of living, such as a great amount of eating outside the home, new theories of nutrition, new forms of commercial pressure? Are the changes which are taking place expansive, associated in people's minds with improved living conditions, or restrictive, associated with a lower standard of living?

Can present trends be projected forward so as to incorporate warnings in present-day educational practice which may anticipate new complications later? For example, may not emphasis upon what each individual should have at a given age and weight—patterned so that a mother serves each child, or expressed in the form of standard table d'hote meals or blue plates—however dietetically planned, if carried too far, reduce the area of physiologically dictated choice and present a new problem when experimental materials on man's ability to make physiologically dictated selections become available?

Moreover, the study of changing food habits provides one of the best areas for a study of the dynamics of food habits. Individuals faced with new feeding situations, school lunches, army feeding, industrial feeding, families faced with new types of foods in shops when they move from one area to another, patients attempting to struggle with a diet—all of these give both observational material and a natural experimental setting which is extremely fruitful. Nutrition education programs, methods of giving individual instruction, or promotion of certain foods can be tested out in the actual observable response of individuals in group feeding situations.

What temporary changes due to war or economic cycle are operating, and how are they operating to form more permanent habits of valuation of missing foods or rejections of alternatives and substitutes? How do different contexts—change toward food indicative of higher social status, change toward better food habits, change toward eating more scientifically—furnish different types of leverage for social change? *Under what conditions are desirable food habits best preserved in a changing culture?*

b. The Study of Stability.

While the attention of applied sciences in our society tends to concentrate upon change as areas of both research and application, the study of those stabilizing aspects of culture which permit individuals to acquire patterned and reliable responses must not be neglected. During the socialization of the child, its original biological impulses toward the gratification of hunger are transformed into socially disciplined appetite. It learns to be hungry at certain times, to sleep long periods without food, to recognize certain foods as appropriate for specific times or occasions, to accept some foods and reject others. These responses insure a positive reaction to familiarly patterned foods for most individuals most of the time, and are a guarantee that the nutritional values which have been embodied in the food practices of a society, either by historical accident or by conscious scientific design, will be available to the individuals who grow up within that society. At any period, whatever the emphasis upon change and improved food habits, there is a major dependence for the nourishment of the people upon their highly patterned food habits.

In studying these factors of stability, it is important to ask in what ways reliance upon familiar foods is patterned. Is the association between food and home made so strong that unfamiliar food produces homesickness and unhappiness? Is the perpetuation of familiar foods intricately interwoven with table etiquette or religious beliefs, so that when these are altered the food itself will change? By restoring some abandoned practice, such as prechewing infant foods to supplement the mother's milk, can an equilibrium be reestablished in the food habits of a group who have displayed extreme malnutrition when some stable factor in their former dietary practices was arbitrarily removed?[475] How are the various food practices linked together so that removal of one food or one method of food preparation may threaten the place of other foods in the diet? A practically unexplored field is the whole question of how a traditional diet embodies a patterning of tastes which is differentially receptive to the addition of foods which will alter the proportion or sequence of the familiar tastes.

One method of studying stability and change in a society is to concentrate attention upon resistances, upon the unsuccessful attempts to introduce new foods or new food practices, and to try to understand how these resistances operate. Food practices which a people refuse to adopt, even under pressure, may thus be used to throw into relief the positive emphases, and help to define the ways in which the stability manifests itself.

While a certain number of non-valuational observations upon the historical background and direction of change will be essential to any study of dietary practices, change is also the area where normative and valuational considerations enter most appropriately.

B. Placing a Problem Within the Cultural Context

Studies of food habits may be arranged along a continuum, as to whether they are primarily the study of the cultural context, in a given section, social group, or period, or whether they are more intensive studies of a limited group of subjects in a controlled situation in which the emphasis is upon experiment or change rather than upon the wider social setting. Among the first type we have studies of American foodways or English foodways which cover a very wide range,[159, 206] those which concentrate on a more detailed examination of a given area at a given period, such as Cussler and de Give's studies of local Southeastern communities today,[161-6, 178] and those which combine a detailed examination of the foodways at a given time in a given section with the invocation of a wider setting of time and space to illuminate further the present local situation, such as studies by Passin, Bennett, et al., of Southern Illinois.[55-7, 464, 465] In an even more extreme orientation of the total culture to the food quest we have books like "Hunger and Work in a Savage Tribe."[514]

In investigations such as these the total frame of reference as outlined in Part III has to be covered, adapted, and amplified for the particular culture being studied. The student relies on a combination of firsthand field observations, written records, statistical summaries, and inferences drawn from records of production and consumption in previous years. The methods used are primarily those of anthropology, sociology, and social history, and the help of the nutritionist is sought when an attempt is made to evaluate the dietary practices, of the economist on the subject of actual or potential resources, of the physiologist if an attempt is made to evaluate nutritional status, the physical resistance, rate of fatigability, etc., of some selected subjects in the area, and of the psychologists to describe the dynamics of attitudes toward food which are systematically observed in individuals who are members of the segment of society being studied.

If records of types of illness are available, especially over a period of time for which other types of records are available, these may be correlated with dietary changes, interpreted by nutritionists (for example, the disappearance of certain types of illness occurring in the spring which were characteristic of earlier periods of American life and which may be related to a decreased vitamin C intake in the winter months), and more subtly still, correlated with the whole system of character formation, if recourse is had to the interpretations of psychosomatic medicine.[27-9, 179, 208-10, 417] * In all studies, however, where the aim is to describe the total setting, every heading in Part III is relevant.

I. INTENSIVE STUDIES

While studies of food habits may actually be arranged on a scale of varying degrees of extensity or intensity, it will point up the methodology more sharply to consider how much of the cultural context it is necessary to include in intensive studies on a selected group of subjects within a controlled situation. The inclusion of wider cultural factors may take different forms: 1) an attempt may be made to place a group of subjects, say twenty fourth-grade children in a Midwestern city, within the total cultural frame, as was done in the studies inaugurated by Kurt Lewin in Iowa City and Cedar Rapids in 1942;[341, 342] or 2) an attempt may be made to include part of the culture of each individual subject in the interpretation of each individual's behavior, the method followed by Dr. Hellersberg[283] in her studies of the relationship between the food habits of college students and the attitudes and educational practices of their mothers as reported on questionnaires.

---

* See Partial Index to Alphabetical Bibliographies, No. 4, Psychosomatic Studies, for additional references.

In the former type of study something must be known about the way in which food reaches the community and is distributed within it, in what forms of preservation and preparation food can be bought or is habitually prepared in the home; what are the ways in which different classes use food to symbolize their social status; what sanctions are used in the home and at school to persuade children to eat certain foods and avoid others. Some historical depth is likewise necessary; the interpretation of the shift of attitudes which was displayed by Cedar Rapids children of different ages [342] would have been incomplete without a record of the intensive nutrition program which had been going on in Cedar Rapids for several years. In such a study the different subcultural groups (for Cedar Rapids these were Negro Americans and Czech Americans) have also to be identified and investigated if only to be certain that the results are not being skewed by systematic differences between the food practices and attitudes of these different subcultural groups.

But a study of this sort in which the behavior of school children is placed against a community-wide cultural context is expensive, involves time and personnel, whereas often the student of food habits will be working as an individual with more limited time and resources. In any study of fourth-grade children, in any community, it is necessary to place them against the cultural background and state to what degree that background is known or unknown. So the range of relevant food production should be stated; e.g., "These children come from an area on the edge of a large city. Some come from farms, some from homes where the father works in a factory but maintains a garden. Some live in small, closely packed houses without any gardens and with slight storage space, and all food is bought." If necessary, the statement can stop here with the added comment, "Type of home from which the children come was not included in the study." In this way other students who have taken these factors into account in pursuing similar problems will be able to evaluate and use the results.

Stated abstractly, this means that each topic should be covered in a general way, if not in detail, and the degree to which the group of subjects are homogeneous or heterogeneous in terms of the various classifications should be stated. Every time a statement like "urban children" can be refined by the addition of such limiting descriptive phrases as "city of X, population twenty thousand, drawing on an area of diversified agriculture," "of mixed national backgrounds, mainly Italian and Polish with no Negroes or Mexicans," "chiefly from families who have entered the city to work in two large industries, coming from small subsistence farms in the Appalachian mountains," etc., the investigation becomes that much more valuable. At each step, of course, it should be stated specifically whether the information is drawn from supplementary sources—social surveys, census records, etc.—directly from the subjects themselves, or from interviews with parents of the subjects. After acquiring a preliminary knowledge of the social setting the student will often find ways of holding certain factors constant. One school may be entirely attended by foreign-born children or children whose parents work in a particular industry, and by systematic inclusion of this circumstance cultural depth can be given to the investigation. There may be an institution from which the children attend the public school, and the known and easily ascertained institutional practices in regard to food in the institution can be used to illuminate the less easily investigated and more diversified home practices.

But in every case it will be found that if the student works through a consideration of the group of subjects in terms of the outline in Part III to determine consciously what he knows, what he does not know, and what he intends to find out, and then states this clearly, the value of any piece of research, both as research and as data on the food habits of a given group at a given period, will be enormously enhanced.

In many types of experiments it will be possible only to describe and control an actual immediate situation, such as eating conditions in a cafeteria, an army canteen, a school lunchroom, and beyond very general statements about age, sex, occupation, and physical status of the subjects, little else will be known in any detail. Here the careful exploration and definition of the immediate situation must take the place of exploration of the wider cultural setting or the culturally patterned life histories of the subjects. In a school lunch situation, for instance, the source of the commodities, the degree to which the menu is controlled by what commodities are available, whether these are surplus commodities or the results of the PTA's canning campaign, whether the lunch is prepared by paid personnel and how those who prepare it feel about it and the children, what the general attitude in the community is toward school lunches, how the children think of lunch at school compared with meals at home—all these immediate situational factors which define the immediate setting can be taken into account instead, while the unknown factors, cultural background of the children's homes, etc., are merely sketched in as unknown or related to very vague generalized social knowledge for that community.

When a series of highly localized situations are taken as the setting for experiments it is necessary to investigate conditions much more closely. For example, if an experiment in acceptance of a new food served in restaurants were made in an old known cultural setting, where the place of restaurants and the role of waiters were so systematic that they could be ascertained by ordinary methods of field work, variations in the behavior of individual waiters might become very unimportant, although a factor to be considered. But in a new, unpatterned situation, as in a recently introduced school lunch program, the personality and behavior of the woman who serves the lunch may be crucial.[277] When an experimental situation is being chosen, a consideration of which elements are highly patterned, and so may be allowed for systematically, and which are unpatterned and have to be explored in particular will be an additional guide in the choice of an experimental setup.

When the student wishes to deepen the experimental results, to shift the emphasis, for instance, from what appeals are most influential in inducing the acceptance of a new food or in what form children are most willing to accept a previously disliked food, etc., to the dynamics of this acceptance or rejection, he will find at once that he needs to shift from his immediate emphasis on immediate behavior to a question of *who* the subjects are in terms of cultural background, differentiated by region, class, nationality, and familial and individual experience. One familiar procedure is to make an experiment ignoring all such factors and then, when intractable results are found, to invoke these factors to explain discrepancies on the order of: "But in School 4 there were many more Italian children who are known to dislike butter on their vegetables and this very likely explains the lower acceptance of the new vegetable in School 4." The systematic exploration of such cultural factors *before* the experiment is made and the careful outlining of those which are excluded should lead to better conceived experiments and more valuable comparative results.

It is granted that the mere accumulation of facts is a technical rather than a scientific task. The same thing can be said of the repetition on a new population of some experiment which has been developed and tried out elsewhere. Both these routine activities, the mere accumulation of more facts of the same order about some new sample and the mere application without change of the same method to a new group, can serve as beginning training ground for students who expect to do advanced work or as part of the technical drudgery of a large-scale survey. But to undertake a problem in this field and *omit to collect the systematic core data* is to make less of a contribution than is possible. Only by combining routine observations and new problems or new methods is it possible for students of every degree of scientific gift to make some contribution to the development of a science, to be sure that the time and labor devoted to a small problem will never be entirely wasted, however poorly some new hypothesis may stand up or some new method turn out.

Investigators can be sure of discharging this obligation by preserving the raw data in some form which is accessible, not necessarily printed but at least in manuscripts deposited in places designated in the published reports. This holds both for the data out of which psychological or sociological abstractions are to be made, when such statements are given as "Nationality, age, and sex were kept constant," and for data out of which nutritional abstractions are formulated, such as "average caloric intake" or "An average intake of vitamin C of x international units was found to characterize the group."

The usual custom is to publish the details of the focus of the experiment and dismiss all of these collateral considerations by formal statements of this sort. When this practice is followed the study is only one link in a chain of investigations in which it will soon be outmoded and superseded, and the raw data collected in order to make the necessary statements about "age held constant" or "average caloric intake" will be lost. If the data on the nationality of the subjects and the detailed diet records which made these two statements possible are preserved and available to subsequent students, our detailed factual knowledge of food habits will be permanently enriched. State university departments of nutrition might well begin depositories of this sort of information, properly indexed and available to other research workers.

If the student stops to consider what a wealth of data lies behind the statements "The arrangement of food in the two cafeterias was found to be identical," "All of the children in the school were found to eat substantially the same breakfast," "The diets also showed a marked riboflavin deficiency," "True and false information tests showed that the children shared very similar ideas of nutrition and attitudes toward nutritional education," "Maternal practice was in accordance with the best current pediatric standards," it will readily be seen what a mass of valuable data is now discarded in the course of making any experiment which involves food habits, records of food intake, attitudes toward change in the field of food, effect of food incentives in learning experiments, discrimination in the field of taste, etc.

2. THE DEVELOPMENT OF FLEXIBLE METHODS

In our preoccupation with standardizing methods, in getting an intelligence test which had been validated on 100,000 school children, we have very often tied our hands. As a portion of the test becomes outmoded, either through a change in education or through an alteration in the cultural content, it becomes less valuable and in the end may have to be done all over again. The validity of the questionnaire on "What did you eat yesterday?" will vary enormously from groups with a low amount of variety to those with a high amount, from groups with a weekly to those with a daily food pattern, etc. If a question of this sort is built firmly into the testing instrument, the instrument becomes rigid and less useful. If we apply our standards of inclusiveness and consistency to the data, and standards of flexibility, new approach, opening up uncharted fields to the *methods* used and problems set, it leaves us much freer to experiment. The student who repeats on Y population an experiment formerly done by Mr. Z with the Q questionnaire on X population can often claim nothing except industriousness.

PART IV

SOME TECHNIQUES WHICH HAVE BEEN USED IN OBSERVATIONAL STUDIES OF FOOD HABITS

IV. SOME TECHNIQUES WHICH HAVE BEEN USED IN OBSERVATIONAL STUDIES OF FOOD HABITS

Observational studies differ from experimental studies, as at best they do not employ only a few highly standardized techniques, but usually rely on a large number of approaches; observation and recording of group and individual behavior, check and exploratory questionnaires, guided and free interviews (both individual and group), analysis of verbatim material and of visual material, use of traditional materials such as proverbs, rituals, folk tales, advertising format, fiction and poetry, projection methods, etc. Studies which confine themselves to a single technique, such as a questionnaire or a check list, tend to be superficial and are usually justified only in preliminary explorations or large-scale quantitative checkup or amplification of initial intensive work.

It is not the purpose of this section to suggest that any one of the methods briefly referred to here, in its particular relevance to the study of food habits, is more than one in a large kit of methodological tools. Nor is it desired to encourage students, as individual research workers or in groups, to use only one of these methods in a study of food habits except in those cases where they are learning the method rather than pursuing a study in which their primary goal is knowledge of food habits. Nor will this manual attempt to discuss the nature of the interview, the technical problems of questionnaire construction, or methods of group observation. The student should refer to specialists and specialist works on these subjects for instructions and models. However, a few cautions and comments are in order on the use of these methods in studies of food.

Food is concrete. Many subjects of social and psychological research do not include among the phenomena investigated any concrete objects, except of course the individuals studied. But in studies of food, the food itself can be seen, measured, weighed, tasted, etc. Reports by individuals of what they eat can be tested against observations of what they ate, of household consumption against grocery receipts, of buying practices against the stock on their shelves. Claims of allegiance to nutritional principles taught in school can be tested against the choices made in the school lunch situation. Food itself can be prepared in various ways and introduced into social situations, and observations can be made on responses to differently prepared or served food. Any study design should take this concrete aspect into account and allow for it as a cross-check on other types of results.

Direct check on food in homes has been used, including consumption studies,[410, 665] records of procedures over time,[25, 184, 410, 422] grocery slips,[282, 367] measurement of food not eaten.[25, 181, 516]

Hueneman and Turner[295] have compared the accuracy of a diet history—consisting of a report by the subject of the previous day's food intake, his "usual" food intake, frequency of eating certain foods, and distribution of food among members of the family—with a diet record consisting of a record of food intake for a period of two weeks. They found that no record agreed with the diet history within 20% for all constituents, and recommended that diet studies be made at intervals over a long period of time. The validity of the method of asking children to "record foods eaten yesterday" has been claimed, but the evidence is insufficient.[20, 605]

Food and food practices of any given group, whether they be the ordinary domestic procedure of the housewife or the trained nutritional approach of the home economics teacher, are complicated. At the beginning of an investigation, students should familiarize themselves with the concrete practices, should not attempt to study food preparation when they do not know the names of cooking utensils or processes, should not compose check lists of food which they know only by name, or test the effect of educational materials using concepts such as "vitamin precursor" which they do not understand. The collaboration in any study of food habits of individuals trained in food and nutrition is highly desirable.

Further, the study of food habits involves the study of a bodily practice about which there are likely to be certain specific types of emotion, shyness, embarrassment, shame, etc. The young child, in the course of learning to conform to the accepted rhythms, patterns, and food choices which constitute the standard nutritional behavior of his social group, has been punished and rewarded, scolded, cajoled, and shamed over the things that he did to his food and the way in which he used his mouth. Many of these early attitudes are likely to color the individual's response both to food and to the interviewer, or color the relationship between those who are eating and a research worker who is watching them eat. The student should be conscious of these difficulties, recognize the extra precautions which will be needed to establish rapport, to dispel any sense that too intimate, too personal questions are being asked, or that the individual's private life is being intruded upon by prying spectators.

In the use of questionnaires, check lists, etc., in which statistical handling of results is contemplated, systematic errors which are correlates of culturally standardized attitudes toward food are likely to occur, such as overestimation of the amount of approved foods eaten and underestimation of the amount of pleasure foods eaten. In a field where there is wide deviation between the educational ideal and actual practice, respondents easily learn to give the approved answers. Some careful work should be done to devise methods of diagnosing these systematic deviations.

Even if students plan to do a very simple study, possibly a guided interview in which a questionnaire or check list is filled out, such as the type of project which Dr. Powdermaker has used with her undergraduate classes at Queens College, Flushing, N. Y.,[495] or such as can be done by practicing home economists or members of local nutrition committees,[828] it will be desirable for the instructor, the student, or the chairman of the research committee to consider some of the longer studies which have used a variety of these methods in approaching the food patterns of a local area.

The studies conducted by Mary L. de Give and Margaret T. Cussler in three selected areas of the Southeast—where conferences with trained people professionally concerned with food, interviews with selected informants, and questionnaires were used—are summarized in "Outline of Studies on Food Habits in the Rural Southeast." [166] Passin and Bennett, with a team of six field workers, made an intensive study of the foodways of a Southern Illinois rural community in which they studied the characteristic and different behavior of several varied sections of the community, the squatters of the riverbottom, the tenant farmer, the Negro residents, the owner farmer, the group who had been on federal relief projects, etc. Several reports of this investigation have been published and it is summarized in "Social Process and Dietary Change." [465]

The most intensive study of food habits using a combined psychological and anthropological frame of reference was conducted by Kurt Lewin at the State University of Iowa in 1942. Intensive interviewing of a carefully selected set of families was followed by the construction of a projective test,[342] in which the reply of the respondent was structured in such a way that much more insight could be obtained into his food attitudes than could be obtained from a questionnaire. This test, a description of which is issued in mimeographed form by the Committee on Food Habits, National Research Council, is suitable for exploring the attitude toward food of any age, sex, or cultural group. It is an exploratory rather than a diagnostic test and so is without norms. Projective tests, in which the subject reacts to material slightly structured so as to turn attention to food, are a useful way of exploring attitudes and can be administered by students with a limited amount of psychological and anthropological training. They do not lend themselves to large-scale machine calculations, as the categories into which machine sorting forces the material obscure the significant nuances.

Hellersberg [283] and Dove [202] have both used the check list method to obtain data for delineating pattern rather than as the basis of simple statements about what percentage of persons ate black raspberries or citrus fruits. Hellersberg constructed a check list with a wide variety of foods of relative high and low familiarity, and used the pattern of the responses in terms of frequency of eating as an indicator of rigidity or flexibility of food habits. Dove, interested not in the individual pattern but in the individual as an indicator of regional patterning, also considered the checking of items in a very large list in their relationship to each other, showing, for instance, how individuals with one regional pattern on moving to another region altered and impoverished the material obscure the significant nuances.

Food interviews vary from the simple form of the subjects reporting what they have eaten, or simple exploration of attitudes toward food scarcity, food advertising, food aspirations, through to the combination of the intensive psychiatric interview with the observations of a social worker, used by Dr. Hilde Bruch,[93] and to the type of deep psychoanalytic interview which is used as the basis for the studies of gastrointestinal diseases.[26-8, 417]

One compromise which makes it possible to use a relatively untrained interviewer and yet obtain useful results is the short interview recorded verbatim in response to a very small number of questions. Such an interview can be conducted by undergraduates who have received introductory training in field methods or by students in other disciplines, and the results analyzed by the method developed by Rhoda Métraux.[409] This same method can be applied to other types of verbatim material, essays by children or adults, letters, etc. The Métraux method organizes the responses into patterns which reveal cultural consistencies as contrasted with other methods of analyzing verbatim materials which are primarily concerned with statistical interrelationships between different units of content. Methods of analyzing interview material in which the percentage of persons responding say that they eat a certain food or like a certain food are of socio-economic interest in consumption studies but contribute relatively less to our knowledge of the dynamics of food habits.

The interview with the expert or professional, as opposed to the more usual type of field interview with a large number of persons selected according to some sampling plan, has proved exceedingly useful in reconnaissance studies. In this method, the student interviews experts who have a wide knowledge of the food practices of some given group, either autobiographically (as when one would approach the study of Syrian food habits by interviewing a home economist who has been reared within Syrian traditions) or through working professionally with members of the group, e.g., the nutritionist of a social agency dealing with people of some definite national extraction. Dr. Natalie Joffe has used both these methods rewardingly in her background studies of foreign nationality groups.[307] Group interviews using controlled discussion among several such experts with experience of the same cultural practices, or among a group of experts with a similar professional background, e.g., public health nurses, nutritionists, home economics teachers, who have worked with different cultural groups, have proved valuable supplementary methods. These methods have been used as backgrounds for more experimental attempts to try out proposed concentrated foods with groups composed of members of a given nationality.[308]

The specific applications of various methods which have been mentioned here have been discussed so that the interested student planning a piece of research will be able to turn to a study illustrating them, or at least an abbreviated account of the study, such as the series of summaries in "The Problem of Changing Food Habits," [6] in which these methods were developed and used in studies of food habits. Many other types of observational approach have never been used in food habits studies but could well be adapted to them.

PART V

EXPERIMENTAL METHODS IN THE FIELD OF FOOD HABITS

V. EXPERIMENTAL METHODS IN THE FIELD OF FOOD HABITS

Since experimental methods are useful only as they are directed toward specific problems, this chapter will be oriented toward the problems that have been studied experimentally rather than toward methodology *per se.* As in the preceding chapters, emphasis is placed on asking appropriate questions, for a question properly stated can be translated more adequately into experimental terms with more rewarding results. Not all the technical details of the methods used will be described nor all the results mentioned. For these the reader is referred to the original studies.

Most of the experiments discussed in all but the last few sections of this chapter have been conducted on animals, as their living conditions can be controlled to a far greater extent than is possible with human subjects. Such studies can test out on a relatively simple level some of the basic questions regarding food behavior under less complex environmental conditions, and can provide considerable information about animals' behavior toward food and the various conditions influencing their behavior, etc., which will be of great value in understanding the most fruitful direction for human investigation and experimentation.

A. UNDER WHAT CONDITIONS CAN A DIET BE SELECTED WHICH WILL MEET PHYSIOLOGICAL NEEDS ADEQUATELY?

Whether appetite uninfluenced by experience with food could serve as an adequate guide to physiological needs was one of the first questions raised and has received continued attention. The early experiments compared the growth rate and weight gains of animals fed standard diets with those of animals placed in a free choice situation consisting of an array of "natural" foods, many of them foods commonly fed to the animals. Under the latter conditions, pigs [222] and cows [443] gained more weight; poultry showed a more efficient and economical use of food [467] and, despite wide individual differences, showed a fairly constant protein intake [256] and an adjustment of cod liver oil intake to the amount of sunlight they received.[257] Rats and mice [415] approximated normal growth but were slightly inferior to animals fed a predetermined diet. Rats, offered a free choice of sucrose, caseinogen, and salt, failed to select a sufficient protein proportion to equal the normal growth of littermates fed a mixture of these substances.[323]

Although early studies revealed wide individual differences [415] in the proportions of foods eaten, Dove [195] demonstrated real differences in animals' *ability* to select a diet permitting satisfactory growth. Several thousand chicks were fed a predetermined diet the first three weeks of life. Then he permitted for eight weeks a free selection of seven foods, all of which are ordinarily fed to chicks, and at the end of each two weeks weighed and regrouped the 10 fastest growing and the 10 slowest growing chicks in separate groups. He found marked differences between the abilities of the chicks in the two groups to "choose foods wisely," which he attributes to many factors, termed "nutritive instincts." Dove[196, 197] shows in later studies that the slowest growing animals are not necessarily inferior in their ability to utilize food. For when the choice made by the "superior" animals, those showing optimum growth and development, is used as the guide to the proper food mixture for the "inferior" animals, the latter show satisfactory growth also, suggesting their inferiority is not due to physiological or organic limitations in the utilization of food, but to inability to select a proper diet.

Richter[586] has further developed the self-selection technique by using chemically pure substances. He first experimented systematically to find which kind of oil, carbohydrate, and protein enabled the rat to live longest when it was the sole item of the diet, and then all these pure food substances were made available to the rats at all times—these three substances plus eight solutions of minerals and salts, the three solids in cups, and the eight liquids in bottles. Intake of each food and activity were recorded daily, weight and vaginal smears weekly. Richter[535] found that "growth, reproduction, and activity were as good as that of animals fed a standard McCollum diet," and that "œstrous cycles were considerably more regular than when they were on the McCollum diet." He also observed that self-selected diets were more efficient than synthetic diets, particularly in pregnant rats who ingested only about half as much food, but remained in excellent health and produced normal offspring.[526] He concluded that animals were able to make satisfactory selections of pure food substances.

Richter[525] interprets this observed behavior of the rats in terms of Claude Bernard's principles "of the maintenance of the internal environment," i.e., if the internal balance or homeostasis is disturbed, the organism attempts to return to the balanced state. If this interpretation is correct, one would expect changes in the internal environment to be reflected in changes in appetite. Richter demonstrates this conclusively in a number of studies. Following adrenalectomy,[524] which disturbs the sodium balance in the body and permits sodium to be excreted too rapidly, rats decreased dextrose intake and markedly increased intake of water and sodium chloride solution so that they did not manifest the usual symptoms of sodium insufficiency. Such rats, treated with a synthetic compound having the same effect as the hormone of the adrenal cortex, reduced their salt intake to approximately a normal level and increased their dextrose intake.

Clark and Clausen[128] confirmed Richter's finding of an increased voluntary selection of salt by adrenalectomized animals, but observed no change in intake of other constituents, possibly because they used free selection of pure foods, whereas Richter used a standard diet mixture with sodium chloride and dextrose solutions.

Richter found similar dietary adjustments when the pancreas was removed;[588] fat intake increased and carbohydrate intake decreased. After parathyroidectomy[581] calcium lactate intake increased. In neither case did the animals show the characteristic symptoms of glandular imbalance. Warkentin, Warkentin, and Ivy[624] observed no difference in the appetites of normal, hypo- and hyperthyroid animals except in caloric intake. More than half their rats failed to select a diet promoting growth when equal parts of yeast and salt mixture were combined, but nineteen out of twenty were able to do so when these constituents were separated. This indicates the importance of complete separation of the food constituents into separate containers, if any separation is attempted. Rats deficient in vitamin B complex showed aversion to carbohydrate and protein, and a craving for fat,[530] apparently attributable to the separate effects of the B components.[528]

In an attempt to understand the physiological basis for this remarkable ability of animals to adjust their food intake to meet a physiological imbalance produced by removal of endocrine glands, Richter first determined whether the animals were more sensitive to the solutions containing the substance particularly needed following the removal of glands by testing the salt taste threshold[520] of normal and adrenalectomized rats. It was distinctly lower in the latter. However, when the taste nerves were sectioned, the rats' salt intake decreased markedly, suggesting that the changes in threshold are due to "chemical changes in the taste mechanisms of the oral cavity."[521] *

One way of checking whether the animal's *appetite demand* for a particular solution is located in the taste mechanism alone or in the chemical state of the total body tissues is to use a substance which has only taste properties and cannot be utilized by the body. Such a substance is saccharin which tastes like sugar but has none of the physiological properties of sugar and cannot be assimilated. After determining the normal food and water intake of 12 rats, Hausmann[279] found that they decreased their food and water intake proportionately when taking sugar solution in addition to the food and water, but did not show such an adjustment, except in water intake, when a saccharin solution was used in place of the sugar solution. This suggests that taste alone does not regulate consumption. It would be interesting to see if this adjustment would be affected by sectioning the taste nerves, as was done with adrenalectomized rats.[521] In another study Hausmann[278] found that rats on a standard McCollum diet, with water and various concentrations of alcohol or sugar solutions, took the same amount of alcohol, independent of the concentration, and the same absolute amount of sugar, adjusting their food and water intake in both cases.

We are interested in knowing whether human beings in a similar situation are able to adjust their intake of specific foods and apparently automatically "balance" their diets. Richter reports several cases of Addison's disease in human subjects who had an abnormal appetite for salt, with dislike of and near aversion to sweets.[522, 644] However, there was no opportunity for controlled experimentation with them.

In the classic study of free choice by children, Davis[171] studied the choices of three male infants for 6 months, and 12 months in one case, following weaning, from among 33 separate high-grade, well-prepared food items, about 10 to 15 being offered at one meal. The children ate in any manner they wished and a nurse assisted only when they indicated a desire for a particular food by pointing to it. Careful records were kept both of the food consumed and the physical condition of the child. Food choices varied widely from day to day; combinations selected were quite different from those ordinarily offered to children; and often definite preferences would appear from time to time, as a child would eat large quantities of only a few foods for several days. All had excellent growth records, and showed no digestive difficulties or eating problems. One child with rickets at the beginning of the study chose cod liver oil over a period of 101 days, when the rickets were apparently healed, and then ceased to take it.

---

* For a discussion of the recent work on the neural mechanism involved in self-selection, see Richter's "Physiological Psychology."[525]

Although Davis' study leads to the ready conclusion that young children, if left alone, can select a satisfactory diet, it demonstrates this only within the conditions of the study.[444] Every one of the foods offered was nutritionally desirable, so that the child could not make a nutritionally "poor" choice except by eating a few and omitting others completely. This happened at times, but the child always shifted to other foods. The study does show that, if a child is offered a wide variety of nutritionally desirable foods before he has developed preferences or has been subjected to any of the social pressures accompanying eating, he can regulate his food intake satisfactorily. It does not demonstrate that once children have had other food experiences they can be expected to choose a satisfactory diet, especially when the variety of foods presented is necessarily smaller, and when foods are likely to be presented in combinations rather than separately.

Richter's experiments with animals show much the same thing—that when the animal is provided with a variety of pure food substances it is able to regulate intake sufficiently well to permit excellent growth and health. The work of both Richter and Davis provides the answer to our first question. We may expect human beings to show the same ability as animals in self-selection *only* if the two major conditions of each study are satisfied in actual life situations: 1) that all the foods available for choice are in such simple or pure forms that each contains only one food element, eliminating the problem of overeating one food to get enough of one of its constituent elements; 2) that our eating could remain a simple choice situation without the social influences such as food patterning, use of food for reward and punishment, etc., which inevitably affect the choice of food. Since these conditions are not provided in actual life situations, we need to look further to see under what other conditions animals and human beings are able to select an adequate diet.

A great deal of work is needed on the precise effect of various food experiences on food choices of young children. Very little experimentation has been done,* although a number of studies have been made by observing the reactions of children to food in nursery school situations.[68, 101, 212, 216, 362, 612, 618]

---

* See Section J.

B. UNDER WHAT CONDITIONS CAN ANIMALS SELECT THE MORE NUTRITIOUS FOOD MIXTURE FROM TWO OR MORE POSSIBLE CHOICES?

In early studies of the ability of animals to choose the nutritionally superior of two or more *mixed* diets, varying in nutritional adequacy, two mixtures differing only in "type or amount of a single constituent" were offered to rats and mice, who generally ate more of the adequate one and showed fairly normal growth. Rats appeared able to detect small quantities of selenium, a toxic substance occurring naturally in some plants, for when offered a choice of four mixtures differing in selenium content, they consistently chose the least toxic.[235]

Harlow [272] found that rats preferred the standard McCollum diet to insufficient ones consisting of three kinds of grain, regardless of whether the criterion of preference was the first food eaten or the relative amount consumed. Blind and anosmic rats showed the same preference. Previous diet * appeared to influence their food choices. Rats fed the McCollum diet plus lettuce preferred it to separate food constituents; while rats fed a low protein diet preferred meat scraps to the McCollum diet, which he attributed to "protein hunger."

Although Price [499] found chicks were able to choose the butter highest in vitamin content, Jukes [311] obtained entirely negative results in a series of studies with chicks, which failed to show a preference between two diets, identical except for the presence in one of vitamin G (lactoflavin), necessary for health and growth. Although accustomed to a diet with a molasses flavor, they did not distinguish between a flavored diet and one unflavored but containing vitamin G.† Chicks with a vitamin G deficiency readily ate a diet mixture containing alfalfa meal, but when offered the basal diet and the alfalfa meal separately, failed to take the latter and many died. In a similar procedure vitamin A deficient chicks did not take enough of the meal to permit normal growth. Jukes suggests that the chicks did not eat the alfalfa meal because of its bitter taste, an explanation also suggested in another study of chicks [602] to account for their failure to select a diet as adequate as a premixed one. Conflicting results have been obtained with chicks, possibly because in the self-selection studies pure food substances have not been used, but rather foodstuffs ordinarily fed to chicks. It would be helpful to use a self-selection technique similar to Richter's and then observe the effect of the palatability factor, which seems to be important.‡ Such a factor may account for the greater number of refusals of rats to eat a low protein diet adequate in cystine content than a similar diet deficient in cystine.[49]

Wilder,[641] studying the ability of rats to distinguish between a rachitic and an anti-rachitic diet, found that 95% of 22 rats maintained on a normal stock diet showed no consistent preference for either of the two diets, but that in the same simple choice situation 68% of the rats maintained on a rachitic diet consistently preferred the anti-rachitic one, while 71% maintained on the anti-rachitic diet consistently selected the rachitic one. He concludes that the choices were not made on a nutritional basis and suggests that the factor of unfamiliarity appears to account for the preferences shown. This finding merits further careful study, particularly in view of other results,* indicating that previous experience with certain food may account for an animal's choice of it from several mixtures. It is also in contrast to the theory of *canalization* [436] that familiar objects are more likely to be preferred to unfamiliar ones.

---

* See next section for discussion of this.

† This is contrary to the finding of Harris and co-workers [276] that rats learned to prefer a distinctly flavored diet when fed it alone for a period of time.

‡ See Section D for discussion of preferences.

Young and Wittenborn [678] attempted to limit the problem further by studying the preferences between 1) cottonseed oil and 2) the oil plus viosterol of three groups of rats fed one of three diets: a) rachitogenic, b) rachitic control, and c) adequate. No preference for either oil was shown by any of the three groups, with the exception of one animal, even after the oil containing viosterol had been placed in the cages of rachitic rats for four days. The absence of preference is not attributed to failure to discriminate between the two oils as one rat preferred the oil without viosterol. They suggest that the failure of animals to discriminate in some instances and not in others may be due to the particular vitamin or food element concerned in the discrimination, but it also vitiates the contention that "the appetite of an animal is an infallible guide in the selection of foodstuffs in accordance with metabolic needs." [678]

That vitamin B deficient rats can detect a diet containing the vitamin has been shown by Harris and his co-workers.[276] A diet flavored with marmite containing vitamin B was preferred almost exclusively to the same diet without any flavoring or with other flavoring. Similar results were obtained when other sources of the vitamin were used; if vitamin B were provided separately from the food, as in orange juice, the rats would drink it, but then failed to select the food mixture containing the vitamin. Richter [584] also observed the immediate preference shown by deficient rats for vitamin B_1 in aqueous solution.

The experimental evidence does not permit an unequivocal answer to Question II. It appears that under some conditions rats can select the more adequate of two or more diets. But what would account for the apparent ease with which rats deficient in vitamin B selected a diet containing vitamin B [276] and the complete failure of rachitic rats to select a diet or the oil containing the needed vitamin D (viosterol),[678] or the failure of chicks to eat alfalfa meal which would have kept them alive? [311] A possible explanation for these differences will be discussed in the next section.

C. WHAT EFFECT DOES PREVIOUS EXPERIENCE HAVE ON THE SELECTION OF FOOD?

Harris and his co-workers observed [276] that the rat could not discriminate between a marmite flavored mixture (containing vitamin B) and 5 to 10 other mixtures, but could be "educated" by simply being offered the marmite mixture alone for several days. During this time the rats recovered considerably and their appetites improved; when offered the choice of the numerous diets again, the one containing marmite was chosen exclusively. When the B concentrate was placed in another mixture, the rats continued to select the one containing the flavor and not the vitamin, thereby showing that the selection was not made on the basis of vitamin B *per se*.

---

* See Section C.

However, Harris reported that they could be "re-educated" at any time to make the correct selection, and attributed the success of the "education" to the "immediate beneficial action of the vitamin B-containing diet," as similar results were not obtained by the same procedure with vitamins A or D, or a protein, none of which produces such immediate improvement in the physical state of the animal. Young and Wittenborn [678] did not succeed in "educating" rachitic rats to prefer the needed vitamin D, carried in an oil and viosterol mixture. It seems very likely that the same explanation applies here—that the effects of vitamin D ingestion are not as rapid as in the case of vitamin B, and therefore the rats cannot "learn" that this is the beneficial choice. It is important to note that the only source of the successful education was a physiological change; with human beings many other motives are involved in any choice of food, and psychological factors may even obscure physiological ones.

To find out if animals could learn to make a nutritionally *in*correct selection, Harris and his co-workers [276] gave the rats one of the vitamin-free mixtures alone for several days. However, when returned to the choice situation, the rats did not choose this one exclusively and in some cases did not eat as much of it as of the others. This question has rarely been approached experimentally, but is a very interesting problem, and should be explored further for more understanding of the nutritionally undesirable choices made by human beings. The effect of different types of reward on the choice between a nutritionally desirable and a nutritionally undesirable food—of receiving a larger quantity of one than the other, of a competitive eating situation, etc.—might be studied experimentally, weighting the choice in both directions. Such a comparison would indicate some of the conditions under which an animal can learn to select a nutritionally inadequate diet as compared with an adequate one. If it could be demonstrated experimentally in animals, the conditions of such a demonstration would add considerably to our understanding.

Other investigators have found that repetition of a food previously refused by animals will increase its acceptance. Young [677] successfully "educated" rats to take a vitamin solution in a free choice situation to replace vitamins in the casein and yeast removed from their diet. The animals refused to touch it except when it was the only source of water in their cages and was offered along with Purina cubes. They continued to take it when returned to the self-selection situation. Although Young does not discuss possible reasons in his brief report, it seems very unlikely that the continued choice of the vitamin solution could be attributed to any beneficial effects which the animals felt from it, as they were not deprived of any food element at the time they first learned to take it. Maslow [383] observed that a large proportion of fifteen dogs refused dog meat at first, but after habituation almost as many accepted it.

Sladden[571, 572] alternated the presentation of two plant leaves, ivy and privet, to stick-insects, first presenting ivy which was frequently refused, and using the privet only if the insect refused the ivy for a certain number of days. The offspring of these parthenogenetic insects who had accepted ivy "rapidly developed an increased ability to accept this plant." She concludes that the "induced food habit," i.e., the acceptance of the ivy, had been transferred from parent to offspring. However, these data may also be interpreted as indicating the existence of an hereditary factor which accounts for the continued acceptance of ivy.

A complete answer to Question C cannot be given at the present time, but it is significant that merely providing an animal with experience in eating a certain food may 1) teach a vitamin B deficient animal to select a distinctively flavored food mixture containing the needed vitamin, or 2) teach animals to accept a vitamin solution they had previously rejected in a choice situation. It is analogous to Lewin's finding[341] that "people like what they eat rather than eat what they like." Further experimental work is needed to determine if immediate improvement in the physiological state of the organism is the significant factor in a rat's educability, and under what conditions this factor operates. It would also be useful to know if rats could be educated to select a mixture containing vitamin B without any distinctive flavor, or lacking both the flavor and the vitamin. This would tell us whether the animal discriminates on the basis of flavor alone or can detect the vitamin B in the mixture through its physiological effect.

The degree of preference or dislike for particular foods * and their relationship to animals' educability is also an important problem. Jukes[311] suggests they are related and that the chicks did not eat the vitamin-containing alfalfa because of its bitter taste. Young and Wittenborn[678] considered that possibly rachitic rats failed to discriminate between cottonseed oil and the oil plus viosterol because of the apparently low palatability of any oil to the rachitic rat. Dove found differences in rabbits' preferences for different varieties of legumes, any one of which provided food substances lacking in the mixed diet.[200]

Another approach to the study of educability is the use of reward and punishment on the preferences shown. This presents a different problem, as we have previously been concerned with the animal's "natural" ability to select a diet and choose between mixed foods, and every attempt has been made to keep the animal relatively "uninfluenced" except for the attempts at "education" by mere repetition of the food. But we need to know more about the type of influences affecting choice of food—how strong and of what nature they must be to change the "natural" choices of the animal. What reinforcements or deterrents would enable an animal to make a nutritionally desirable or a nutritionally undesirable choice? The greater complexity of the attitudes and reactions of human beings to food emphasizes the importance of introducing other factors into experimental work with animals.

---

* Discussed in the next section.

D. DO ANIMALS EXHIBIT PREFERENCES, AND, IF SO, WHAT ROLE DO THEY PLAY IN THE SELECTION OF FOOD?

Bayer [44] studied the food preferences of chickens, mixing five grains each of two cereals and observing which was chosen first. Six hens showed a consistent preference for rice when compared with the other cereals.

Harlow [272] believed that male albino rats showed definite food preferences immediately after weaning, but his evidence is not conclusive as he used one nutritionally adequate mixture and three kinds of grain, none of which was adequate in itself.

Young has studied food preferences extensively, utilizing a runway leading to a platform in the center of which are placed two test-tubes which are filled level to the top with the two foods or liquids to be compared.[670] In order to eliminate the position factor both test-tubes are alternated in position. The rat may nibble or sniff at both foods, but the one actually eaten is recorded and as soon as a preference is shown (usually in 1-4 seconds) the test-tubes are lowered out of reach. The rat is trained to run back and forth from the starting box to the platform. A food is said to be preferred if selected for six consecutive trials or if it is eaten more often and at the same time the other is not tasted. Young has established the serial principle, also observed by others,[64, 384] that the *relative* preference for different foods can be expressed as a series with no reversals—if A is preferred to B and B to C, then A is also preferred to C, etc. This indicates the existence of different appetites for separate foods, varying independently.[675]

Young concludes that "preferential habits are definitely acquired; they result from practice." [677] This is a particularly important point for those interested in the development of food habits. According to Young's criteria, a series of trials is essential before preferences can be shown. In addition, it is to be expected that the rats, having had no experience with either food used in the preference test, would not show preference until they had become familiar with both foods; preference cannot be expressed between two unfamiliar objects. In other words, soon after weaning rats showed preferences for one food to another when the sole experience with either was in the food testing situation, where both were presented equivalently. It is important to note that some rats do not show preferences, regardless of the way in which the apparatus is manipulated in attempting to force a discrimination.[673]

Young [677] recently combined the self-selection method of maintenance with preference testing, using only components of the maintenance diet in preference tests, so that an accurate record of the total daily intake of the group of rats can be obtained. When first placed in the self-selection situation, their intake of sugar, one of the most preferred foods, was very large, but gradually leveled off to a relatively constant intake, as it did with the other foods except for the mineral solutions.

Stone [596] describes a method for demonstrating olfactory sensitivity in the rat, placing in the corners of the cage four food-cups, three containing presumably unpalatable flavors. If the rat rejects the three and eats from the other, it is assumed that he can detect the unpleasant flavors. French [289] describes a 5- and 2-choice situation, in which the food-cups are covered with a coarse wire mesh permitting the rat to obtain food by use of its paw only. Either method would seem applicable only for the study of discriminating odors which had been demonstrated to be "unpleasant" to rats; otherwise the rat might prefer the odor to the unflavored food.

Dove [200] developed a different technique for studying the relative palatability of natural foods by supplying rabbits with a food mixture complete except for the legume, two varieties of which were presented in equal quantity at the same time. Using the relative weight eaten as the criterion of preference, fourteen varieties of legumes and eighteen of cabbage and kale were compared and arranged in rank order of palatability, revealing differences between different classes of legumes as well as subgroupings within each class.

These studies indicate that preferences are shown very soon after weaning by rats whose only experience with the two foods has been when the foods were in equivalent positions. Apparently some explanation other than the animal's experience with food must be used to account for these consistent preferences. Young points to good evidence for at least "ten independently variable partial hungers or appetites." However, this does not account completely for the occurrence of preferences, as animals deprived in one food substance, such as protein, may continue to prefer another (sugar) in the preference test as long as the choice is made by the head receptors.* [677]

E. UNDER WHAT CIRCUMSTANCES CAN PREFERENCES BE CHANGED?

Bierens de Haan [64] found striking differences between Cebus monkeys and Macacus and Cercopithecus monkeys in their reactions to several variations in preference tests after their relative preferences for seven foods had been determined. The several Cebus monkeys were affected very little by the variations, but the others showed considerable changes when the less preferred food was doubled in quantity. However, further increase in its quantity produced relatively little change, and even a ratio of 10:1 did not change the preference between the most and the least preferred foods. When the more preferred food was placed farther away than the less preferred, little change in preference occurred; when both quantity and distance were changed in favor of the less preferred, great conflict was expressed by the animals and a drop in preference occurred. Covering the preferred food with a transparent or a blackened glass made little difference in preference after the animals had become accustomed to the situation.

Nissen and Elder [447] also found that the behavior of chimpanzees was readily influenced by changes in the size of their banana reward; when it was increased they were able to stand greater delays and yet respond correctly. That variations of this sort produce real differences in animal behavior indicates the importance of controlling adequately all the conditions of an experimental study.

Young [677] has used a standard procedure of testing animals' food preferences after 24 hours deprivation. The fact that there appear to be "partial hungers" or "specific appetites"[675] for certain food constituents, however, suggests that satiation with a particular constituent might change the relative preference value of this food as compared with others. Young[674] studied systematically the effect of controlled prefeeding on food preferences of a group of 11 rats after their definite preference of sugar to wheat was determined. No change in preference occurred until they were given free access to an unlimited supply of sugar in the prefeeding cage for 15 minutes, followed by a 15-minute preference test, with more opportunity to eat the test-foods, when all showed a clear and unmistakable trend in the direction of preference for wheat, preferring it consistently by the fourth day. When the prefeeding was omitted, the original preference for sugar was gradually restored by the end of five days. Young suggests that if the appetite for sugar had merely been satiated, an immediate reversal might have been expected once the prefeeding was discontinued, but since this did not occur, he thinks the rat was "conditioned to taking wheat."[677] Similar shifts in preference have also been demonstrated.[674]

---

* See next section for discussion of this.

Young found also[677] that rats, placed in a free-eating situation with, for example, both sugar and wheat available, will spend a decreasing proportion of time eating the originally preferred food, sugar, and will eat more and more wheat, until a change occurs and wheat is preferred.

Other experimenters have observed the effect of satiation on food preferences. Bayer[44] reports that hens overate when rice, the preferred grain, was given them for a three-day period, and at the end of this time showed less preference for it. When wheat, less preferred in the beginning, was fed in the same way, their preference did not change. Apparently the animal becomes satiated more quickly with the highly preferred food; Young has suggested this also in the comparison of sugar and wheat.[674]

Hausmann[278] established satiation with alcohol, which the animals avoided for a considerable period of time after it had been the only liquid in their cages.

In testing the food preferences of primates by placing ½-inch cubes of the two foods to be tested in opposite corners of a black table level with the cage, Maslow[384] observed that the preference seemed to change during a series of 25 choices. Very possibly this was due to satiation.

These studies of shifts in preference when satiation with one food occurs are of considerable theoretical interest as they provide good evidence for the existence of specific appetites; otherwise, satiation with one food would mean satiation of all hungers. They also suggest numerous questions which, if answered, might throw considerable light on the bases for preferences and the interrelationships of partial appetites. Is the reversal in preference due to physiological changes? Can any preference be reversed? Can a permanent reversal be produced? What other conditions in addition to satiation will produce a reversal in preference?

Will a physiological need for the less-preferred food induce a change in preference? Young studied this[677] by first establishing rats' preference of sugar to casein, then removing all protein (both casein and yeast) from their diet and continuing the preference tests. Even after 29 days of complete protein deprivation, the rats preferred sugar to casein.

He then developed a method of testing preference which differed from the original one (called the "foods-together" technique), in that the foods were apart, so that the choice-point was not immediately in front of both foods but was back at the starting place. He eliminated sensory cues by placing the food under the level of the bin, and dishes of each test food near the other, but not accessible, so that the same olfactory cues would be present in both places. Using this method, he found that after 29 days of protein deprivation, the rats preferred casein to sugar. This suggests that there are two kinds of preference, one when the "head receptors are forced to function," and one "when the head receptors are eliminated." Young attributes the preference in the foods-together technique, when the choice is made by the head receptors, to what we call the "palatability" of the food and the preference in the foods-apart technique to "some deep-lying organic factor with the head receptors eliminated as factors in the immediate choice."[677] This extremely important finding opens up a new approach to the whole problem of food choices. What is the nature of preferences shown when the foods-apart technique is used? Are they the same as those shown by the foods-together technique except when the animal has a particular deprivation? Under what conditions does satiation occur and are its effects the same?

F. WHAT EFFECT DOES DEPRIVATION HAVE ON FEEDING BEHAVIOR?

This specific question is related to the general one of the effect of previous experience on eating behavior. Although deprivation in animals is exceedingly different from deprivation in human beings, it is useful to observe in animals some of its simplest effects, uncomplicated by the many influences affecting the behavior of humans. Observation on this level can furnish valuable clues to the investigation of the highly complex phenomena in human beings.

Festinger[220] studied the effect of *relative deprivation* by permitting rats more of one food than another and observing their relative preference for the two foods. Whole wheat grain and dry milk, having very similar preference value according to Young, were used. After 12 hours deprivation rats were given forced runs, and every fourth day free choice between a "ten-second feeding on one food and a one-minute feeding on a different food." Half the experimental group were given the shorter feeding on wheat and the other half on dry milk. At the end of 24 days the animals ran to the food with which they had experienced the longer feeding only slightly more than 50% of the time, while a control group, given similar feeding periods on only one food, ran to the alley where they had had the longer feeding almost 100% of the time. The proportion of runs to the food with the longer feeding period increased steadily as deprivation time was increased to 24 hours, but remained the same when deprivation was increased to 36 hours. Festinger interprets these results "in terms of the one food's becoming more attractive to the animal because of the relative deprivation." It would be useful to see if strong food preferences, for example, sugar to wheat, could be reversed by this method, or if a change in the choice points, the significance of which

Young demonstrated,[677] might produce different results. Introducing the factor of physiological need for one of the foods plus the variable of the choice point would provide more information about the effects of relative deprivation.

The effects of general deprivation have also been studied. It appears to be the most important factor contributing to hoarding behavior which has only recently been studied experimentally. The criterion of hoarding is the carrying of food from the food box to the home cage, the two separated by an alley approximately 2 to 3 feet in length. Pellets are used, as the animal could not carry loose food, and standard size pellets can be counted easily and provide a quantitative measure. Morgan and his associates[425] found that usng the criterion of at least 5 pellets carried to the cage was very satisfactory and differentiated the animals who were consistent hoarders and those who were not.

In an exploratory study Wolfe[655] found that hoarding behavior could be studied quantitatively, as a group of 10 adult rats under constant conditions of hunger showed fairly consistent food-storing behavior during 30-minute periods on consecutive days. Rats fed pellets following weaning hoarded more pellets than rats fed the same food in powdered form, although they were under the same conditions of hunger motivation (24-hour deprivation), showing that experience with food in pellet form contributes to hoarding behavior.

In summary, the general experimental procedure for studying hoarding behavior has been to start immediately at weaning and control the living conditions of all the rats until divided into control and experimental groups. The methods generally used to equate the groups are to split litters or to match individuals or groups in age and weight. McCord[364] used preliminary hoarding rate as the basis for equation, but found wide variations among members of the same group, suggesting that this is not entirely satisfactory or a longer period of observation before equation is needed. Some conditions, varied experimentally, and their effect on hoarding are the following:

1) Rats fed pellets following weaning hoarded more than rats fed the same food in powdered form, when under the same conditions of hunger motivation.[656]

2) Rats fed an inadequate diet immediately or soon after weaning hoarded significantly more pellets than rats fed an adequate diet during this same period. When the diet conditions were reversed and the rats tested immediately afterward, those having experienced deprivation most recently hoarded more pellets, but the difference was not nearly so great as in the first instance.[685] When rats were tested five months after deprivation, they did not hoard when satiated, but after a subsistence diet for five days the group deprived shortly after weaning hoarded 2½ times as many pellets as the control group, whereas the group deprived at the age of 32 days hoarded slightly fewer than their controls.[296]

3) The group which had experienced the early deprivation ate more food during the first part of the feeding period when placed on the subsistence diet as adults, suggesting that the *rate of eating* may be an important indication of the effect of earlier experience.[296] Young[673] has developed a technique for recording automatically the rate of eating, including measures of the weight of food eaten per unit of time, and suggests that the "*rate of approach to satiation* is the proper index of an animal's demand for a given food." Because this rate varies according to the "preference-value" of the food, hoarding studies in which pellets of separate food constituents were used should yield some illuminating results.

   Kleiber and Smith[321] also observed a more rapid rate of eating after a one-day fast among rats whose food intake had previously been restricted than among others who had not been so restricted.

4) When the conflict between eating and hoarding (reported by Hunt[296]) was studied systematically[425] by giving animals the first half-hour after 23 hours deprivation for eating only and an opportunity to hoard during the second half-hour, and vice versa for other groups, more hoarding occurred during the second half-hour than the first. When 24-hour deprivation periods (23 hours deprivation and one hour feeding) were alternated with 24-hour satiation, the average number of pellets hoarded was greater on the days when the animals were satiated than when they were hungry.[425]

5) More hoarding occurred after longer periods of deprivation (23 and 36 hours) than shorter (12 hours). Under satiation, the curves of hoarding showed similar drops.[425]

6) No differences in hoarding were observed when the hoarded pellets were removed from the rats' cages at the end of the first third and the second third of the hoarding test.[425] However, the rats would not hoard wooden blocks.[412]

7) Seeking to evaluate the relative importance of experience and deprivation in producing hoarding behavior, Stellar and Morgan[586] used two closely matched groups, placing them in the hoarding apparatus daily during the same 18-day period. One was given an unlimited supply of food and the other placed on a 24-hour deprivation schedule. The latter hoarded considerably more, leading to the conclusion that the chief contribution to hoarding "comes from deprivation."

8) When two closely matched groups were placed on a 24-hour deprivation schedule the one which had had an opportunity to hoard during the 18-day period hoarded considerably less than the group which had no opportunity to hoard during the same period. Furthermore, the latter group started to hoard at a higher level and hoarded 100% more than the other group, suggesting that the "drive to hoard may be deprived."[586]

9) That the familiarity of the animals with the apparatus is an important factor in hoarding behavior is shown by the finding that rats hoarded an

average of 4 times as many pellets to a home cage as to a strange cage which was equally accessible.[412] When rats had become familiar with the alleys by feeding in them for one week. the onset of hoarding behavior was greatly accelerated. The explanation suggested is that the unfamiliar situation produces emotional responses inhibiting hoarding.[615]

10) Olfactory cues (shavings from home cage placed in strange cage) are more important than visual (fresh shavings placed in home cage) in facilitating hoarding, but do not produce optimal hoarding.[412]

Numerous interpretations have been offered for hoarding behavior, principally 1) on a physiological basis and 2) on a learning basis. Morgan and his associates consider hoarding behavior as primarily "the result of food deprivation," and attribute it to "the creation of some deficit in the body, which requires considerably more food deprivation than does hunger for reaching a crucial level, and takes a greater amount of food intake to relieve than does hunger." [425] It may be either an exhaustion of some specific material such as blood sugar or a general lowering of metabolism. To find out whether certain physiological states might account for it, Stellar [585] studied the effects of injections of glucose, insulin, and epinephrine, but the only significant change resulting was a marked depression in hoarding when epinephrine was used, perhaps from the general depression of activity which it produces. However, he suggests that shortcomings in the experimental procedures may account for the absence of other significant changes.

Wolfe [655] has suggested that tissue needs are a major determinant in producing hoarding behavior. One might conclude that a diet sufficient to maintain body weight only is actually a more severe deprivation in younger than in older rats, but Hunt [296] found no relationship between the degree of inanition during infantile deprivation and the amount of hoarding. Possibly the conflict between eating and hoarding occurred, and the rats more severely affected physically ate more and hoarded less. This could be tested experimentally. Hunt believes that his findings, that rats experiencing feeding-frustration shortly after weaning hoard significantly more than their controls, while rats experiencing similar frustration at the age of 32 days do not hoard more than their controls, provide evidence for the general claims of psychoanalysis that experiences in infancy influence adult behavior. He interprets them in terms of learning theory, that "internal stimuli serve as conditioned stimuli," and that feeding-frustration produces a greater emotional reaction in the younger rats and a consequent greater retention of the effects.

It is also possible that an early experience of deprivation becomes integrated into the physiological pattern, and consequently its effects are retained, whereas a later experience does not have such pronounced effects. Other work has demonstrated the vulnerability of the young mammal to changes disturbing basic biological processes. Ribble's work [511] with infants has shown the close relationship of the sucking activity with breathing and muscular relaxation, and the severe reaction occurring in young babies when sucking is frustrated. The neurosis Masserman [387] produced in cats by means of an air blast just as they were ready to eat may also be attributed to the interference with the fundamental process of eating. Further work is needed to show just how early experiences affecting the physiological systems of the young mammal are integrated with the functioning of these systems.

Considerable experimental work must be done to test these various interpretations. One way of determining whether the "psychological effects" may cause hoarding behavior is to keep the actual physical conditions identical. McCord [364] has conducted an experiment of this sort; each rat in the "deprivate" group was fed one-half a pellet twice a day, while each one in the "frustrate" group received the same amount of food, but was given the whole pellet, and as soon as half was eaten, the other half was placed in a wire receptacle left in the cage, which the animals gnawed at trying to reach the pellet. The "frustrated" rats hoarded more than the "deprived" rats, but there was considerable variation in the groups, possibly because of the method used to equate them.

The study of hoarding is important because it offers an opportunity to study the effect of previous experience on the behavior of rats toward food and a means of measuring this easily in a quantitative fashion. Even when the hoarded pellets are removed, the animals continue to hoard, which suggests that the behavior is not related exclusively to physiological conditions, although it may have been originally, but continues and has no direct relationship to the satisfaction of immediate hunger, since animals hoard more when satiated than when hungry. Its relationship to specific deficiencies has not been explored but is a most interesting question. Also, the relationship between deficiencies and preferences in hoarding behavior remains to be determined.

G. IN WHAT WAY DO SOCIAL AND EMOTIONAL CONDITIONS INFLUENCE BEHAVIOR TOWARD FOOD?

A number of studies indicate the importance of considering in any study of food behavior the social situation in which an animal eats.

In studying the social facilitation of feeding responses of chickens, Bayer [44] found that a satiated hen ate 25-30% more food in the presence of an actively eating hen, and 33-67% more with three actively eating hens. If three satiated hens were placed with one eating actively, the effect was much less, about 10% more food being eaten. The dominant hen always attacked the other, regardless of whether it was satiated or hungry. Hens eating in groups of four one day and separately the next would eat on the average 96% more food in groups.

Guhl and Allee [265] compared the effect on hens of living in a stable flock, in which the peck-order was well established, with that of living in isolation and of living in a constantly reorganized flock, in which no permanent peck-order could be established because of the introduction of strange hens. They found that the isolated hens approximately equalled those in the organized flocks in eating behavior, egg-laying, and weight gains, but that the hens in the disorganized flocks ate less and lost weight. They suggest that "organized flocks of hens possess qualities that might have survival values in nature." This approach opens up many new problems for study, and shows the importance of taking into account the social situation in which the animal's behavior is studied. What is the relationship of position in the peck-order to Dove's[195] "superior" and "inferior" individuals? Are those who are best able to select a diet permitting optimum growth always highest in the peck-order? Guhl and Allee propose to study the effect of mixed flocks, and suggest comparing the behavior in groups in which the animals have been previously trained to fight and those in which the animals have been trained not to fight. What sort of social organization is evolved by a constant and a frequently changing group under these conditions? What effect does it have on their eating, weight gain, and egg-laying?

In a study of the effect of social facilitation upon behavior in the rat, Harlow[273] found that a satiated rat did not eat more in the presence of a hungry rat. However, rats having no previous experience with solid food regularly ate more in a group feeding situation (2 to 5 rats) than an equated group ate as individuals. And when rats had previously lived and eaten in groups of 4 or 5, much greater facilitation was evidenced in the quantity they ate when fed in pairs on alternate days. Such findings point to the need for further study of social influences, since active excitable behavior is known to inhibit smooth muscle contractions.

Bayroff[46] studied the effect of early isolation of white rats on their later social behavior, but used as the indicator of their "social behavior" their choice between a compartment containing animals and food and one containing only food, or between one with only the stimulus animals and an empty compartment. In general the preferences appeared to be made on the basis of position of the cages only.

Harlow and Yudin[274] fed Macacus rhesus monkeys in pairs from the same cup in the same cage, from separate cups in own cages, from separate cups in own cages and one between within reach of both, and from cups located in the adjacent corners of each cage so that each monkey could reach the other's cup as well as its own. In almost all cases facilitation occurred, the degree appearing "as a function of the active competition between the monkeys," that is, the more competition between the two animals, the more each ate. It was more pronounced in the case of a little-liked food, bread, than oranges, which they preferred.

Other studies have been made on the food sharing behavior of chimpanzees. Nissen and Crawford[446] placed two cages side by side. In one was a food-delivering apparatus which all the animals had learned to use by inserting a poker chip and thereby obtaining a small piece of food. Food and tokens were supplied only to the animal *not* in the same cage with the vender. Tokens were transferred more frequently than food, whereas begging and positive responses occurred more frequently between animals who were close friends.

Nowlis[451] studied the relation of the degree of hunger to the behavior of chimpanzees in pairs in different competitive situations. When both were equally satiated, regularly fed, or underfed, the more dominant took the piece of banana presented through a chute more than half the time. When it was satiated, however, and the subordinate member underfed, the latter took the piece more than half the time; only one-third of the subordinate members when regularly fed took the piece more than half the time. The results indicate that the "frustration-response" varies "with the strength of the food-drive" in the dominant animal, but "varies slightly with the strength of the food-drive and more importantly with the degree of expectancy or response" in the subordinate animal.

Nowlis[450] tested preference by placing a chimpanzee in a choice situation in which it could approach either of two other chimpanzees and share peanut kernels. No relationship was found between preference status and food sharing, which occurred only 16% of the time, but there was a relationship between dominance (measured both by food-getting and escaping first from a small cage) and food sharing; the two dominant animals received 73% of the food, and the two subordinate gave 76% of the food shared. The most dominant animal never shared and the most subordinate never succeeded in getting food from its partner.

Mowrer reports[429] that adult rats will develop a well-defined ascendancy-submission hierarchy if forced to compete for a 6-gram pellet, that "subordinated rats tend to develop a 'food neurosis,' becoming fearful of eating in the experimental situation even though no other animals are present." Even their problem-solving capacities are likely to be affected.

These experiments show how essential it is to observe every aspect of the situation in which the animal lives and eats. They also indicate the extreme complexity of the eating situation for human beings. Much further work could be done with animals, placing them in different types of living and feeding situations, subjecting them to reward and punishment for certain types of feeding behavior, and observing the effect not only on their feeding behavior but on their social interaction with other animals.

Mowrer studied the development of social behavior in young rats and found that it passed through three stages: non-competitive, competitive, and food sharing. Sharing did not occur if the animal securing the pellet could run into a compartment out of reach of its cagemates, and did not occur in older animals if the same size pellet was used. When sharing behavior was learned, it continued in adulthood, but severe competition occurred if an animal without similar training entered the group. When three rats were put together, after learning individually to press a bar to obtain a pellet, a "social problem" was created, as the animal pressing had less chance to get the pellet. All tend to give up the bar-pressing until very hungry, and then one will "attack the bar, biting and shaking it," producing many pellets, a few of which it gets. A "few repetitions convert the bar-attacker into a confirmed 'worker' and the other two into chronic 'parasites.'" This is an interesting report of the social organization of animals in the food-getting situation. It would be useful to study the relative dominance and submission of the "worker" as compared with the "parasites" and the condition under which this behavior could be modified.

Cannon[102] demonstrated many years ago that emotional reactions inhibit smooth muscle contractions of the stomach which produce the sensation of hunger as well as of the digestive tract after food ingestion. Studies of the more precise relationship between the two are increasing our understanding of the close relationship of all the bodily functions. Scantlebury and Patterson[557] recorded the contractions in the empty stomachs of two human subjects by the balloon method and determined the normal rhythm. They then found that the greatest inhibitory effect of various psychic phenomena (not described in detail) on the rhythm occurred during the second two-fifths of the hunger period; if they took place earlier some inhibition occurred, but the total number of usual contractions took place; and if they took place later, the contractions were so near the final tetanic phase that nothing stopped them. In the psychosomatic field Mittelman and Wolff's investigations of the relationship between emotional reactions and stomach secretions, which include the experimental production of lesions through the presentation to the patients of material based on analysis of their life histories, are classic experimental studies.[417]

Bousfield[78] attempted to test the hypothesis that emotionally disturbed animals eat relatively more sugar, since sucrose is relatively easily digested, by placing each experimental animal in the cage of a belligerent animal (determined in a previous study) one-half hour before eating, and then removing it to the home cage where sugar and dog chow were available. He observed a tendency for the experimental animals "to increase their relative sugar consumption after fighting," but the results are not conclusive. The effect of the increased activity before eating should be considered; it would be desirable to place the control group in a situation where they received an equivalent amount of exercise but were not involved in a highly "emotional" situation.

Bousfield's experiment suggests a number of other variations—feeding each experimental animal in the cage where the fighting took place, both immediately after the fighting and during a period of time afterward, to see if eating in the same cage affected behavior toward food. Also, the animal's reaction to 1) a preferred and 2) a relatively unpreferred food in a fighting situation in the same cage and in the home cage might provide information on the effect of the emotional experience of belligerency upon food preferences. Whether a relatively unpreferred food becomes more attractive when eaten by a rival animal is an important question. Harlow and Yudin's study[274] indicated that facilitation of eating was a function of competition between the monkeys, and more pronounced with a little-liked food such as bread than a preferred food such as oranges. Is facilitation ever sufficiently strong, however, to change a later reaction to such foods when the subjects are away from the social situation producing it? This is a problem of conditioning on a higher level.

Gantt[248] extended a conflict based upon food to other physiological systems by forcing dogs to make "difficult differentiations of signals for food."

Liddell[344] discusses the abnormal behavior which can be produced in sheep, dogs, and pigs during conditioning experiments, and emphasizes the importance of considering the relationship between the animal and the experimenter as an essential part of the situation. His conditioning method for the pig involved a choice between two signals, one indicating food in the box and one for no food, but he attributes the development of an experimental neurosis not to the difficulty of discrimination but to at least two other factors, "the monotonous and 'unsatisfying' repetition of stimuli according to a fixed temporal pattern, and the tensions developed by the animal's self-imposed restraint within the Pavlov frame." However, the animal's behavior toward food became distinctly abnormal, and finally the pig did not open the box to obtain the food until the experimenter entered the room to release it from the apparatus, when the animal rapidly ate the food in the box. Masserman[387] produced neurotic behavior in cats by subjecting them to an air blast just as they were ready to eat. Further study of the changes in food behavior resulting from conditioning experience, both when food is a direct part of the conditioning situation and when it is not, should yield valuable results. Does the "neurotic" animal behave abnormally toward food when away from the conditioning situation, when the food is identical with that used in conditioning, or when the experimenter is present?

Experimenters using other types of discrimination have produced experimental neuroses in animals by requiring them to make increasingly difficult discriminations. It would be useful to employ a food choice in similar situations and observe not only the animal's reaction to the experimental situation, but also to its entire life situation.

H. WHAT TYPE OF BEHAVIOR HAS BEEN USED TO STUDY INTENSITY OF HUNGER?

Studies of hunger concern us here because data on food habits can be obtained from studies using hunger as motivation. Does degree of hunger change over a period of time? Does the drive remain at approximately the same level during progressive starvation? Is it periodic? Is its increase at certain times due only to the animal's previous experience in eating at particular times, or is it related to a physiological cycle? Some of these questions have been answered fairly satisfactorily; others require further study.

There is considerable evidence that, although the sensation of hunger in human beings is accompanied by contractions of the stomach,[102, 289] the hunger or food-getting drive continues in animals whose stomachs have been removed[603] and in those whose sensory nerves leading from the stomach to the brain have been sectioned,[41, 423] as shown by rate of learning with food as the incentive and by obstruction methods. This suggests that hunger relates to a physiological condition not localized in the stomach. Its precise nature is not understood at the present time.

The strength of the hunger drive has been measured by the use of electrical obstructions, obstructions which must be gnawed through, and motor responses, and is assumed to vary in degree as the strength of the obstruction overcome.

Warner[625] and Warden and Jackson[623] used electrical obstructions to study the hunger drive in rats during varying periods of food deprivation, while Margolin and Bunch,[377] using a similar method, found an inverse relationship between age and the strength of the hunger drive, which they suggest may be due to changes in the motility of the stomach with age.

Skinner [569] considers the rate of responding, i.e., pressing a lever to obtain a pellet, a truer indication of "drive" than could be assumed by giving different animals the same amount of food or equal feeding periods. He equated groups according to rate of responding, and validated the method by comparing their extinction curves, which were very similar. Similarly, Heron and Skinner [285] studied changes in hunger during starvation by reinforcing the lever response every four minutes with a small pellet of food. The number of responses to the lever per hour increased to a peak after an average of five days starvation, with the range from 4 to 14 days. Fitts,[231] in a preliminary report of a study in which the Skinner lever-conditioning apparatus was used, concludes that the "relationship between the degree of hunger, as measured in time since the previous feeding, and number of responses necessary to bring about experimental extinction is not a simple one."

Finan and Taylor [228] found the rate of response, i.e., of pressing a bar to obtain food, was considerably less reliable as a measure of motivation than either the number of responses or the total time required for extinction of this conditioned response. Another approach that permits quantitative study of the hunger drive is the pecking activity of chicks, which, with hunger, increases in energy but decreases in accuracy.[81]

Changes also occur in rate of eating. The amount rats ate regularly during a given feeding period decreased with increased deprivation,[80] probably paralleling physiological changes, as studies have shown the stomach undergoes contraction with decrease in food intake. In view of this, one cannot assume that providing an animal with only a limited feeding period each day, e.g., twenty minutes, will enable it to eat the same quantity of food day after day because, as the animal reaches further degrees of inanition, it eats more slowly.

Bousfield and Elliott,[80] discussing the methodology of such studies, emphasize the necessity of considering periodicity in the eating rhythm, and suggest establishing a definite eating rhythm prior to the experiment and then observing the behavior of the animal at the time he is normally fed. In other words, it is essential in such studies to establish a norm of behavior against which to measure variability.

Another aspect of this problem is the study of hunger demand for single food elements. The most widely used index is the weight of food eaten per unit of time. Using the apparatus described above,[569] Skinner determined the curve of approach-to-satiation and the equation for the curve. Young [678] obtained similar results, but suggests that "the rate of approach to satiation, rather than the absolute rate of eating, is the proper index of an animal's demand for a given food." This index is the same in principle to the "coefficient of voracity" proposed earlier by Bousfield.[77] Such an index permits comparison of relative preference value and relative hunger demand for various foods, and observation of changes in each when the animal is satiated with certain foods.

A different technique for studying the relationship between hunger and behavior was developed for use with human subjects by Sanford[552-3] to investigate the relation of the intensity of a need to the amount of perceptual distortion. He used tests of word association, interpretation of pictures, chained association, completion of drawings, and completion of words—all constructed to elicit possible responses related to food—and found that, although college students who had fasted for 24 hours averaged more food responses than students tested immediately before their normal eating time, the increase of the former group was not in proportion to the increased time of going without food. In fact, the frequency of food responses after 15-20 hours of fasting was smaller than that after either of these other intervals. Sanford interpreted this in terms of a "food habit," i.e., that the subjects customarily ate at certain times, and that as a result hunger occurred at the time they normally ate, and subsided to a certain extent between these periods. He attributed the occurrence of the greatest number of food responses after the twenty-four hour fast to both the "food habit," since the test came at noon, and the "physical need for food."

Levine, Chein, and Murphy[339] did further work on this problem, presenting to subjects, at intervals of one to nine hours after eating, a series of 80 ambiguous figures, half in color and half in black and gray, including 15 pictures of food, 15 of household articles, and 15 meaningless ones. The control group gave relatively constant responses to the pictures, while the experimental group gave more food responses to the achromatic cards after both 3- and 6-hour intervals, but gave less after the 9-hour interval than at any other time. On the colored cards, the decrease in food responses occurred between the 3- and 6-hour intervals. The experimenters suggest that two processes operate, that "the autistic process is in the direction of gratification," and that "beyond a certain point more ambiguous figures favor the reality process, making it more difficult for the autistic process to proceed." The results might be interpreted either as indicating that actual hunger decreases between the 6- and 9-hour periods, or that it becomes more intense so that pictures of food are not satisfying and the subject is interested only in real food. The authors believe the second interpretation is the correct one, however, as the number of rejections (refusal to give name to the picture) increased as the length of the hunger period increased.

These studies raise a number of other questions regarding the patterning of hunger in human beings. We know that a definite hunger rhythm can be established in animals.[80] Does this occur with human beings also? Is hunger experienced at certain times because the individual is generally accustomed to eating at those times? In societies where the customary meal pattern is one meal or two meals a day, does hunger occur after a different interval of time than in groups accustomed to three meals a day? To what extent does the attitude that certain foods are appropriate for certain meals influence what will be eaten to satisfy the hunger; for example, will an individual in our society eat for breakfast foods that are customarily eaten only at one of the other two meals in the day, such as salads, raw and cooked vegetables, etc.?

If he refuses them at first, will he accept them if he has been deprived of several meals? What happens to the appetite for certain foods when an individual has had nothing to eat for varying lengths of time? A study of individual variations in hunger and attitudes coupled with a careful study of the previous training received by these individuals might throw further light on the way food behavior is patterned.

I. WHAT TECHNIQUES HAVE BEEN DEVELOPED TO STUDY THE FOOD AND TASTE PREFERENCES OF HUMAN BEINGS?

In this section we are concerned only with studies directed to the problem of taste sensitivity related to preferences, for although the questions of gustatory sensitivity, its relationship with olfaction and with kinesthetic and temperature sensations and others are of great interest, they are pertinent to the field of food habits only as the sense of taste is related to the attitude or behavior of the subject. Both Platt [488] and Sweetman [599] discuss some of the methods of studying palatability and the assumptions on which they are based.

Davis [173] found that infants showed definite taste preferences among four formulas offered in randomized order, and Chaney and McGraw [114] observed among neonates distinctly different reactions to various tastes.

Psychophysical methods immediately suggest themselves as applicable to this sort of problem. In a study [330] of changes in taste preference accompanying increase in age, Laird and Breen used the method of least perceptible differences "to establish uniform degrees of separation along the sweetness scale," and finally selected five degrees of sweetness of pineapple juice for comparisons. The preference curve for the youngest group closely paralleled the middle groups; while the oldest groups shifted toward increased preference for tart tastes.

In other studies [255, 314] no attempt was made to control the way in which the subjects compared the samples of bread, but they were asked to mark them in order of preference and to record reasons wherever possible. Dove [201] describes a technique in which eight subjects judged the palatability of 18 varieties of sweet corn, comparing six varieties at one sitting, ranking them in order, and recording their reasons for ranking. Then the two which had been ranked first and second in each group were compared, those ranking third and fourth were compared, and so on, so that a hierarchy was built up. Dove suggests choosing certain varieties from the total hierarchy so that any additional variety could be compared with them and given the appropriate rank.

In attempting to select persons with taste discrimination, Moir [418] used varied tests, including a series of sugar solutions to be arranged in order of sweetness, and others devised to see if the subjects were misled by the appearance of the foodstuff. For example, he mixed colors and flavors of table jellies so that the color was not associated with the usual flavor. Similarly, sponge biscuits were chocolate colored, but one was flavored with cocoa and the other with vanilla only. These tests indicated an individual's ability to separate taste from visual characteristics commonly associated with the taste. Traditionally, the coffee and wine "tasters" are well known and doubtless some of their practices offer valuable clues to research along this line.

It would be helpful to know how keen is the taste discrimination in human subjects, including gustatory and olfactory cues, between disliked or rejected dishes and other dishes resembling these in flavor or consistency, and what sort of discrimination can be made when only kinesthetic cues are present. Blindfold tests in which the subject is given samples of well-prepared food, 1) with no indication as to what they are, 2) when simply told that they are kinds of food which he likes or will accept, and 3) when told what the food actually is, will provide information as to whether rejections of particular kinds are on the basis of taste, texture, or "ideas" associated with the name of the food. The reaction of the subject when told he is to be given a particular kind of food but is actually given another kind, differing in taste, texture, or temperature, would add to our understanding of the factor of "expectancy" in eating. A study of the taste discrimination between dishes of food—some of which contain a constituent which is refused or disliked because of no previous experience with it—and of the relative preferences for the dishes when their constituents are known would indicate the extent to which this knowledge influences the reaction.

J. WHAT TECHNIQUES HAVE BEEN USED TO CHANGE FOOD CHOICES OF HUMAN BEINGS?

Food preferences of animals have been changed by 1) satiating the animal with the preferred food, in which case its preference usually changes,[674] 2) allowing the animal a consistently shorter feeding period for one food than another, in which case he prefers the one he has had less time to eat,[226] and 3) changing the physiological state of the body by surgical operation or qualitative deprivation, so that the animal prefers the food substance for which he has an increased need,[522] and will choose it even in preference to a previously much preferred food if the head receptors are not involved in the choice.[677]

It is fairly common experience to most human beings that satiation with a particular food produces at least a temporary preference for other foods and perhaps dislike for the particular food. However, few studies have been made of the ways in which food preferences of human beings are changed. It is a problem much more difficult to study experimentally, since their lives cannot be controlled to the same degree as the lives of animals, their previous experiences with food cannot be accurately recorded with the techniques we now possess, and although we know that attitudes toward food are inextricably bound up with the manner in which children are taught foodways, we do not yet have comprehensive records tracing the development of these attitudes. In view of the infinitely more complex conditions in which the food habits of people originate and develop, it is fruitless merely to imitate the experimental methods used in studying the behavior of animals toward food. A wholly different approach is indicated in order to obtain results of practical value and not simply abstractions solely applicable to the highly controlled conditions of the laboratory. The context in which people live must be considered as part of the study and taken into account in interpreting results. If it is desirable to equate groups for a study, it is preferable to do it on the basis of present behavior without assuming a similar past experience in regard to food unless the data documenting psychological or cultural regularities are available to support such an assumption.

Repetition of food has been used to overcome food dislikes. After first determining attitudes of women college students toward evaporated milk, Hollinger and Roberts [292] served a small portion of reconstituted milk sixteen times during four weeks; at the end of this time 51%, as compared with 14% at first, indicated a liking for it.

This finding suggests the importance of the factor of availability, which undoubtedly contributes greatly to the development and changes of preferences in human beings. A study like the above could be enlarged to examine the modifications in preference when the foods available are changed. Undoubtedly accepting one new, originally disliked food is different from accepting a number of them at once; a very interesting problem in this connection would be to see whether there is a critical level beyond which none of the strange foods would be accepted. Such a study could conceivably be made with nursery school children as subjects. The importance of motivation for accepting or rejecting foods must be considered. The attitudes of adults and their reactions to an entirely different diet in a strange country may depend greatly upon their general reaction to the new situation, such as the desire to "belong" to the country.

The fact that we generally prefer the familiar to the unfamiliar scarcely needs experimental demonstration but has been shown to apply to food [353] as well as to other objects.[356] It is very likely that the mechanism of *canalization*,[436] that is, that the objects first providing satisfaction to the individual are persistently preferred to others, even though the later ones might provide greater satisfaction when accepted, operates. Such a mechanism would account for the persistence of preferences for nutritionally undesirable food combinations, for example. A great number of food combinations or single foods can satisfy hunger, and once this satisfaction occurs there is a greater likelihood that the individual will prefer the familiar foods at a later time. This is identical with Lewin's finding that "people like what they eat, rather than eat what they like." [341]

Gauger [250] made a detailed study of 17 nursery school children in a standardized situation for 35 days. They were given four distasteful (as judged by the children's reactions) stimuli—vinegar, strong salt solution, weak salt solution, and raw egg white—each followed by a very small piece of milk chocolate. The greatest modifications in their reactions, rated by observers, were in regard to the strong salt solution and vinegar, disliked the most at first. Reactions to all the stimuli, including chocolate, decreased in intensity. Gauger concluded that the important factor in teaching a child to like a disliked food is to keep the situation free from emotional elements. However, considering the importance attached to chocolate in our culture, one can scarcely consider it a "non-emotional" factor.

The effect of social influences on a child's food preferences has been studied by Duncker.[211] Nursery school children were first permitted to choose the food they "liked best" from six different foods, and then each one was given a later opportunity to choose immediately after another child whose choice he observed. There was 81% agreement in choices when one observed the other, compared with 26% agreement when they chose individually. When age was varied systematically, the younger child more readily imitated the older one; however, children under about 2⅔ years of age did not "follow," and no children imitated an adult.

Marinho[379] continued this type of study to see if the imitative effect would last. Using 4- to 6-year-olds in kindergarten, she first tested each child's preference for the fruit pastes used, and then told the child (chosen because of his dominance or ascendance in the group), whose choice was observed, either to select the fruit paste the other child had been avoiding or, if the other child had shown no preference, to select one fruit paste regularly. It appeared easier to set up a definite response in individuals not having a definite preference to begin with, since the children starting out with indefinite preference showed the greatest change, both immediately and later, in tests conducted four to seven weeks and a year afterward. In studying the effect of the personalities of the children chosen to be the "leaders," i.e., make the choices observed by others, Marinho found that, although only a few children observed the choice made by a "domineering" leader, none was appreciably influenced by this leader.

Duncker[211] observed the effect of telling a lively story to a group of young children during which they were given a taste of two solutions; the first tasted very bad according to the story, but actually tasted very good, and the second was supposed to taste very good, but actually tasted very bad. The storytelling lasted about five minutes, but Duncker found a definite after-effect, lasting between 6 to 12 days, revealed in the children's preference for the second solution as compared with the first. He interprets the change as due to a change in *meaning* of the object and possibly to accentuation of favorable elements within it. This is a very important finding, as there seems little doubt that the *meaning* of any food object to a person is an important determinant of the individual's reaction to it, and that if the *meaning* of a disliked food can somehow be changed, it will be accepted. We will return to this point later.

The studies already described dealt with changes in regard to specific food over a limited period of time, often in artificial surroundings. Studies related to more general food consumption, if conducted in homes, would require a tremendous expenditure of time and energy merely to record accurately the foods used and the way they are used over a period of time.[25] Their results would be complicated by numerous uncontrollable variations, such as cooking skills of housewives, families' eating customs, etc. One means of avoiding these complications and of utilizing a fairly standard situation is to study food consumption in cafeterias, where every customer has considerable freedom of choice from among the same individual items (except when meals are patterned as "special" lunches, etc.), and where the selections may be easily recorded.

A few essential conditions for a cafeteria study may be stated on the basis of studies already completed: 1) The population of the cafeteria must be fairly static, so that the choices made at one time can be compared with the choices made by the *same* people at a later time. The easiest way to meet this condition is to use a cafeteria serving a particular group of people, such as those working in the same building or in a given factory, and sufficiently isolated from other eating places so that the same people patronize it regularly. 2) Some control must be exercised over the menus in order to provide data which can be interpreted with some degree of validity, for obviously a choice of a meat dish from four meat dishes is very different psychologically from choosing the one meat dish offered. Although one approach would be to keep the menus identical, this may be very difficult unless the observation periods are separated by a considerable lapse of time. Minimum requirements are: 1) that the number of items—of meat dishes, breads, potato dishes, etc.—should be the same throughout the entire study, and 2) if a particular item is being studied, for example, meat dish, the "comparison" dishes, i.e., the other dishes occupying the same place on the menu, should be the same. Other requirements depend upon the specific problem.

There are a considerable number of factors probably influencing food behavior which can be recorded and evaluated during the course of the study. Some which seem of patent significance are weather conditions, the entire menu served each day, and any unusual or other conditions which appear to have any relationship to choice of food.

Three possible experimental designs for cafeteria studies are suggested: 1) a comparison of the consumption of the customers before and after the experimental conditions are introduced, and 2) a comparison of the consumption of customers in separate but identical cafeterias at the same time, introducing experimental conditions in one or more, and keeping one or more as the control, and 3) a combination of the two. If either of the last two is used, an additional condition must be insured, namely, that the population and conditions in each cafeteria are equivalent. Consumption records during an initial "control" period should be kept in order to establish a norm with which subsequent behavior may be compared.

Using the first design, Ready [505] studied the effect of changing the number of variations in dishes on the breakfast menu of a hospital cafeteria with a fairly static population. When the number of egg dishes and fruit dishes was increased from one each to three each, a significantly greater number were sold. Decreasing the number of choices by one (two fruits and two breads instead of three) had the reverse effect. The findings of this study apply only to menus containing a relatively small variety of dishes, for obviously there is an optimum point beyond which there is no value in increasing the number of dishes. They indicate that the number of variations of a particular food may be an important determinant in the frequency of choice of that food, and reinforce one of the cautions expressed above—that the number of the particular dishes being studied must be kept constant.

The first type of experimental design was also used by Lund [384] in a study of food choices made by junior high school pupils in a school cafeteria. The first four months served as the control period, and the experimental period lasted for six months. The educational materials consisted of 1) talks given in homerooms by student council members on health, etiquette, and civic responsibilities, 2) posters relating to the foods, generally emphasizing health and growth, placed in the cafeterias, halls, and homerooms, 3) commendation slips placed on the trays of pupils choosing "A" lunches, and 4) articles in the school paper. This type of study is limited in two ways; in the first place, weather, available foods, school activities, etc., differ considerably in the fall and spring semesters, and undoubtedly influence food choices made by any group over such a long period of time; secondly, the educational materials were not planned to test the effectiveness of any type of appeal, but were apparently chosen because they were considered effective. The results were not conclusive, but if they had been, all that could be said would be that "with the type of educational materials used," an improvement in the food choices was shown.

The third type of experimental design was used in a study of the relative effectiveness of different combinations of appeals used in presenting a new food —soya.[661] The appeals were based on an analysis of the pattern of verbatim attitudes which showed that soybeans were not yet conceptualized as food, but that certain appeals (nutritional value, American rather than Oriental food, good value for your money, variety) might lead to a favorable conceptualization.[660] Sets of four posters, carrying different combinations of these appeals, were identical except for the legend, and were placed in each of four identical cafeterias: 1) all four appeals, 2) all except for nutritional value, which was omitted, 3) only nutritional value, and 4) all except "good value for your money," which was omitted. Two other identical cafeterias served as controls. A different soya dish was served on each of five days during the week, all combining soya products with familiar food in a familiar form, in a bread, a meat dish, a meat substitute, a soup, and a dessert. This permitted study of reactions to the *idea* of eating soya products. The name of the dish on the menu included the word "soya" except for the first week when records were kept to indicate the "normal" consumption of each. Records were also kept during the week before the posters were put up, the week the posters were up, and the week after the posters were taken down. The records covered the first two hours of the luncheon period and were kept separately for men and women.

The conclusions are based principally on the statistical significance of changes in consumption in each cafeteria during the week the posters were up. They indicate consistently that the most effective combination was the one in which no mention was made of the nutritional value of soybeans, and that the least effective was the nutrition appeal used alone. This is attributed to the fact that soybeans are an entirely new food, with which customers have no pleasant associations. Because foods which are thought of as "good for us" are considered different from those which are "good to eat," particularly if their taste is unfamiliar, emphasis on the nutritive value of a new food is likely to imply that it is not "good to eat," which in turn would account for the negative reaction to this appeal. Such a reaction is not as likely to occur, of course, to information about the nutritive value of a food which is already accepted and liked.

A plan similar to that used in cafeteria studies could be used for an experimental study in a community, although there would be many more uncontrolled factors. Young[667] describes in detail a method for evaluating a community nutrition program by using the sales records of both retail and wholesale grocers, but does not describe the educational campaign.

In any "real life" situation, however, accidental or uncontrolled events are almost unavoidable. Variations in food supplies available at stores, in weather, in the advertising appearing in the stores, etc., are but a few of the many changes which may occur.

A number of attempts have been made to evaluate nutrition education programs experimentally. Gillett and Rice[252] conducted two such studies, evaluating the food habits of the families studied on the basis of the cost and quantity of food consumed. In a study of 135 tuberculous families,[82] the food and health habits of all the children were rated on the basis of information given by the mother both at the beginning of the study and nine months later. The findings indicated an increase in consumption of the protective foods, greatest among the families with whom the nutritionist worked individually, but also among the families the nurses worked with, as compared with little change in the control group. A further evaluation of the specific educational techniques used in studies of this type would be helpful to those interested in nutrition and nutrition education.

Another method of changing food habits is that of *group decision,* developed by Lewin[343] and Bavelas.[47] Briefly, it consists of a discussion led by a skillful leader in which the members of the group come to regard the matter being discussed as important to themselves and begin to take over responsibility for it, until finally, after some of their objections and statements of difficulties have been aired and discussed, they are ready to reach a decision which is actually a decision made "by the individual concerning her own action."[341] The effectiveness of this method was compared with that of a lecture method in getting housewives to use glandular meats. In the lecture, the nutritionist talked for approximately half an hour about the nutritional advantages of using the meats, easy methods of preparation, etc.; whereas in the group decision method, the nutritionist participated when questions about preparation were raised and her technical information was needed. Each method was used in one group each at the high, middle, and low income level; the results, obtained a week later by interviewing each of the women, showed a large difference in favor of the group decision method, as 44% of the total women (44) in these groups and only 3% of the 41 women in the lecture groups served one of the glandular meats "they had never or hardly ever served before." It would appear that this method is a successful one even with fairly deep-seated food prejudices, as glandular meats were a highly disliked food.

Willerman[645] compared the group discussion method with a lecture method in attempting to increase the consumption of whole wheat as compared with white bread in student cooperative houses. Although his results are inconclusive because the supply of bread was not constant, he found that the reaction to the proposal to participate in the experiment, the students' eagerness to reach their goal, and even their relative preference for whole wheat bread (all rated on scales by the students themselves) depended upon the degree to which the decision was made by a majority. If made only by a very small majority, the group's attitudes were more negative than those of the members of the houses who were asked to try to reach an arbitrary goal, demonstrating that a group decision must actually be a group decision by a considerable majority, particularly where it involves the behavior of all the members at the same time, as it would in a group eating situation.

From the preliminary work done, the group decision method appears to be very worthwhile for further experimental work. Some of the questions that should be investigated are: 1) How long can the effect of the group decision be expected to last? Would it carry over from the group eating situations to choices made by the individuals in other eating situations? Do the housewives continue to use glandular meats? 2) Can decisions be made with different "time perspective," i.e., some which have only immediate carryover value, and others which have more lasting effects? 3) Is there any relationship between the *kind* of change which the group decides to make and the effectiveness of the decision; for example, a change in cooking practice, etc., rather than the use of a new food or the increased use of a familiar food? Are there differences in effectiveness when the change involves behavior which is on a completely individual basis, or concerns one's family or group, or can be observed by the members of the groups making the decision?

K. WHAT EFFECT DOES NUTRITIONAL STATUS HAVE ON LEARNING ABILITY AND PERFORMANCE?

This question is somewhat tangential to the main focus of our attention in this chapter but is of great importance, as good nutrition is considered a means to the goal of good health and efficient performance. Much of the experimental work has been conducted with rats, with maze-learning the chief criterion of learning. In such studies it is extremely important to use an incentive unrelated to the deficiency and it is preferable not to use food at all as an incentive. Aside from the fact that a deficiency in any one dietary constituent may affect the general appetite just as a vitamin B_1 deficiency produces anorexia, is the fact that with normal animals the effectiveness of different foods as incentives varies, probably with their preference-value and also with the relative amount offered.[64, 226, 262] Since we do not yet know whether or how preferences vary with changes in nutritional status, it would be unwise to use a food which might actually differ in its incentive value to the experimental and control groups. Water (with thirst as the motivation) has been used, but there is probably a complex relationship between thirst and hunger which might vitiate the results. Escape from water appears to be the most useful motivation at the present time, as it is unrelated to the deficiency state and provides continued motivation until the animal leaves the maze.

Rats nursed by mothers fed a diet deficient in vitamin B complex [59] or in B_1,[391] and those treated in this way and also fed a vitamin B complex deficient diet after weaning,[490] were inferior to their controls both in rate of learning the escape from water maze and in retention. Growing rats fed a vitamin B_1 deficient diet showed similar inferiority in learning and retention in an escape from water maze.[489] Stevens' [590] failure to find a consistent inferiority of B_1 deficient animals in maze-learning may possibly be attributed to his use of hunger as motivation. Rats whose diets were not depleted in vitamin B until the age of 90-100 days were significantly inferior to their controls in running time but not in errors, but showed marked individual differences in performance.[241]

Early deficiencies in the B complex or vitamin B_1 appear to produce a more marked deteriorating effect than a later deficiency in vitamin B_1[61] or a deficiency in vitamin B_2,* [433, 491] probably because of the relationship of vitamin B_1 to the developing nervous system.[681] There is also evidence that B_1 is involved in the chemical changes occurring with the transmission of the nervous impulse [441] which would account for the sensitivity of the system to B_1 deficiency. Animals deficient in vitamin B_1 acquire significantly fewer conditioned responses (eyelid reflex) than normal littermates; [63] the use of conditioning eliminates any possible motivational differences between deficient and normal animals which may occur in studies of learning ability and provides a technique for studying the functioning of the nervous system. Patton, Karn, and King [466] found that when equated groups of rats were fed the identical basal diet but given different amounts of vitamin B_1 and tested for susceptibility to convulsive seizures produced by auditory stimulation, there was evidence for a critical level of vitamin B_1 intake falling between the minimum and maximum intake, which resulted in maximum sensitivity.

On the other hand, rats fed a diet deficient in vitamin A, or in iron and phosphorus, did not show inferiority in learning.[60, 390, 420] Negative results were obtained when rats were fed a "native Mexican diet," [630] or a rickets-producing diet.[234] McCarrison [337] demonstrated the superiority of the Sikhs' diet over a diet "resembling that eaten by many Western people of the poorer classes" by feeding both to equated groups of rats and observing the growth effect.

Although a number of studies purport to show that rats whose growth was stunted by early feeding deficiencies [32, 322, 330] were superior to their control groups in maze-learning, it seems very possible that the difference in maze-learning was due to a motivational difference (greater hunger) rather than to a real difference in ability. Biel [62] tested this possibility by depriving control animals with previously normal growth so that their weight was reduced as much as possible and yet permitted their running the maze. Comparison showed their performance was approximately the same as that of stunted animals, suggesting that degree of hunger is an extremely important factor in maze-learning when food is the motivation. It would be preferable to utilize a source of motivation unrelated to hunger and appetite in studies of the effect of stunting on learning.

---

* It is important to remember that in the experiments completed before the isolation of niacin (1938) and pantothenic acid (1938) the term B_2 may refer to a substance including not only riboflavin, which is synonymous with the term B_2 at the present time, but other components of the B complex. Since the physiology and biochemistry of nutrition is a field of specialization quite apart from experimental psychology, it is necessary to call upon specialists within it for assistance in any study including a nutritional problem.

Further understanding of the basis for changes in behavior produced by a deficient diet has been obtained by studies of the effect of vitamin deficiencies on the structure of the developing nervous system. When rats were fed a diet deficient in vitamin A, they developed lesions in the nervous system after 10 to 12 weeks of normal growth;[653, 682] these lesions are apparently due to mechanical causes, that is, stunting of the braincase caused overcrowding and produced lesions in the nervous system. An overgrowth of bone and degeneration of the eighth cranial nerve has also been reported in young dogs deficient in vitamin A.[407] Lesions of the nervous system have been experimentally produced in pigeons, rats, and dogs fed a diet deficient in vitamin B_1.[681] Rats fed a diet free from vitamin E from the time of weaning showed psychomotor disturbances accompanied by neurological and muscular changes at the age of ten months.[419]

Studies of the effect of vitamin deficiencies and vitamin feeding on human behavior have used principally two criteria of changed behavior, 1) change in mental performance and 2) change in work output. Summarizing earlier studies of change in mental performance, Fritz[248] concludes that none of the studies with children as subjects indicates that diet markedly affects intelligence. He points out, however, that the relatively short sampling periods of behavior, such as an intelligence test, may not reveal differences in capacity. It also appears possible that the relatively short length of time during which the improved diet has been eaten may not permit clear changes to appear. Balken and Maurer[38] reported that young children showed an increased efficiency of performance on mental tests when their diet, previously deficient in the vitamin B complex, was supplemented by it. Harrell[275] fed tablets to all the children in an orphanage; half received tablets containing thiamin and the other half received placebos. She found that the group receiving the thiamin showed an improved performance in code learning, reading, and arithmetic.

Adult schizophrenics, given vitamin supplementation (A, D, B_1, B_2) and iron, showed a significantly greater improvement on the Arthur Performance Scale, administered three times at intervals of six months, than a carefully matched control group.[39] Four middle-aged women, given a diet deficient in the B vitamins, showed an inferior performance on maze tests, but no difference on tests of general intelligence, reasoning ability, or hard-muscle coordination.[461] The effect of vitamin administration on the symptom picture of adult psychotics[270] and of children with nervous diseases[320] has also been studied. Such studies, however, would be of greater value if a dietary history, complete record of dietary intake during the course of the study, and examination of nutritional status had been included. Obtaining adequate records of this sort is one of the problems involved in experimentation with human subjects.

Within the last few years a number of studies of the effect of vitamin intake and deficiencies upon the work output of adult men have been made in which more complete records of dietary intake and nutritional status have been kept.*

The rigidly controlled experimental situation which Keys and his co-workers [318] have developed provides an unusual opportunity for study of the influence of reduced vitamin and food intake on both motor and mental performance as well as on various personality traits of young men. Much of the data is still unpublished, but when available will provide valuable information concerning the effect of vitamin deficiencies on mental performance.

---

* See summary discussions [188, 616-8] for appraisal of these.

PART VI

HOW TO FIND REFERENCES IN THE FIELD OF FOOD HABITS

VI. HOW TO FIND REFERENCES IN THE FIELD OF FOOD HABITS*

Since food habits may not be a separate category in many library catalogues and, even if it is, may not include many of the references in which the individual doing research is interested, the following list of headings is suggested for source material: diet, dietetics, nutrition, food, cookery, agricultural economics, agricultural statistics, public health, consumer demand, consumer education, child training, eating, etc. Since different schemes of cross-references are used, it is safer not to depend upon them but to check all the possible sources. The following indexes have proved useful:

Nutrition Abstracts and Reviews. Published since 1931. Detailed abstracts and comprehensive indexing of each volume. For regional dietary studies look under the heading "Diet" for the particular region of the world.

Experiment Station Record. Published since 1889. Detailed abstracts of experiment station and U.S.D.A. publications, and of research related to food and nutrition reported in other publications. Best source for food consumption studies conducted in this country.

Psychological Abstracts. Published since 1927. Abstracts of articles appearing in psychological journals principally; good source for experimental work conducted in psychological field. Look under the headings: appetite, food, hunger.

Agricultural Index. Published since 1916. Indexes to most of the agricultural journals published in this country and to many published elsewhere.

Quarterly Cumulative Index Medicus. Published since 1927. Comprehensive index to most medical journals, including many published in other countries.

International Index to Periodicals. Published since 1907. (Readers' Guide Supplement until 1920.) Index to many of the journals in fields of anthropology, sociology, psychology, political science, history, etc.

Readers' Guide to Periodical Literature. Published since 1919. Primarily an index to popular periodicals.

---

* The assistance of Dr. Mary L. de Give in the preparation of this statement is acknowledged.

PART VII

BIBLIOGRAPHY

This selected bibliography has been compiled to provide orientation in the problems of food habits and the methods and techniques used to study them. Within the United States, we have listed studies because they contain concrete data, whether or not they are of special theoretical or methodological interest. Outside the United States, we have attempted to select classical studies, such as the report of the League of Nations, and a few articles that have a theoretical or methodological interest or which might serve to stimulate cultural awareness in American students.

ORIENTATION BIBLIOGRAPHY

1. American Academy of Political and Social Science Annals. Nutrition and food supply: the war and after. 225: 1-279, 1943.
2. American Medical Association, Council on Foods and Nutrition. Handbook of nutrition, a symposium. Chicago, A.M.A., 1943. 586 p.
3. American School Health Association. Special nutrition number. J. School Health, March 1944. 82 p.
4. Bigwood, E. J. Guiding principles for studies on the nutrition of populations. Geneva, League of Nations, Health Organization, Technical Committee on Nutrition, vol. 3, no. 1, 1939. 281 p.
5. Black, John D. Food enough. Lancaster, Pa., Jacques Cattell, 1943. 269 p.
6. Committee on Food Habits, National Research Council. The problem of changing food habits. NRC Bull. 108. Washington, D. C., 1943. 177 p.
7. Food and Nutrition Board, National Research Council. Inadequate diets and nutritional deficiencies in the United States. NRC Bull. 109. Washington, D. C., 1943. 56 p.
8. Food and Nutrition Board. Recommended dietary allowances. NRC Reprint and Circular Series, no. 115, 1943. 6 p.
9. League of Nations. Problem of nutrition. Geneva, 1936. 4 vols.:
    - I. Interim report of the mixed committee on the problem of nutrition. 98 p.
    - II. Report on the physiological bases of nutrition. 27 p.
    - III. Nutrition in various countries. 271 p.
    - IV. Statistics of food production, consumption, and prices. 110 p.
10. League of Nations. Final report of the mixed committee of the League of Nations on the relation of nutrition to health, agriculture and economic policy. Geneva, 1937. 327 p.
11. League of Nations Health Organization. Intergovernmental conference of Far Eastern countries on rural hygiene. Preparatory papers:
    - Report by the preparatory committee. Geneva, 1937, p. 55-74.
    - Note on public health organization in Burma. Note on public medical organization in Burma. March 1937, p. 23-27.
    - Report of French Indo-China. March 1937, p. 74-101.
    - Preparatory papers relating to British India. Geneva, April 1937, p. 45-69.
    - Report of the Malayan delegation. May 1937, p. 23-27.
    - Report on health organization in Ceylon. April 1937, p. 40-49.
    - Report of the Philippines. April 1937, p. 16-25.
    - Report of China. May 1937, p. 50-62.
    - Report of Japan. May 1937, p. 25-29.
    - Report of Siam. May 1937, p. 36-44.
    - Reports of Hong Kong, North Borneo, Sarawak, Fiji, Gilbert and Ellici Islands Colony, British Solomon Islands Protectorate, New Hebrides Condominium, Tonga. May 1937, pp. 22-24, 32-35, 49, 70-76, 88-89, 109-112, 120-122.
    - Report of the Netherlands Indies. June 1937, p. 118-144.
    - Report of intergovernmental conference of Far Eastern countries on rural hygiene. September 1937. 119 p.
12. League of Nations. Report on the work of a group of experts appointed to study methods of assessing the state of nutrition in infants and adolescents. A. Introduction. B. Recommendations made by the experts. C. Bigwood, E. J. The methods of assessing the state of nutrition in infants and adolescents in relation to defective diet. Geneva, Bull. of the Health Org., 6: 129-136, 137-140, 141-204, 1937.
13. League of Nations. Secretariat. Survey of national nutrition policies, 1937-38. Geneva, 1938.

14. League of Nations, Health Committee. European conference on rural life. General technical documentation. Rural dietaries in Europe. Geneva, 1939. 84 p.
15. McCollum, E. V., Orent-Keiles, E., and Day, H. G. The newer knowledge of nutrition. New York, Macmillan, 1939. 701 p.
16. MacLeod, G., and Taylor, C. M. Rose's foundations of nutrition. 4th ed. New York, Macmillan, 1944. 594 p.
17. Nutrition Advisory Committee to the Coordinator of Health, Welfare, and Related Defense Activities. Minutes of the national nutrition conference for defense, May 1941. Govt. Print. Off. 253 p.
18. Orr, J. B. Food and the people. London, The Pilot Press Ltd., 1943. 56 p.
19. Reid, M. G. Food for people. New York, John Wiley & Sons, 1943. 653 p.
20. Sherman, H. C. Chemistry of food and nutrition. 6th ed. New York, Macmillan, 1941. 512 p.
21. Sherman, H. C. The science of nutrition. New York, Columbia Univ. Press, 1943. 253 p.
22. Sherman, H. C., and Lanford, C. S. Essentials of nutrition. 2nd ed. New York, Macmillan, 1943. 442 p.
23. United Nations Conference on Food and Agriculture, Hot Springs, Virginia. May 18-June 3, 1943. Final act and section reports. Pub. 1948, Conf. Series 52. Govt. Print. Off., 1943. 61 p.
24. United States Department of Agriculture. Food and life. Yearbook of agriculture, 1939. Govt. Print. Off. 1165 p.

BIBLIOGRAPHY *

A

25. Abrams, M. L. Special social surveys in Great Britain. Conf. of Comm. on Food Habits, Nat. Res. Council. *In* The problem of changing food habits, p. 170-171. *See No. 6.*

26. Adlersberg, D., and Houser, T. Special diets under rationing. J. Am. Dietetic Assoc., 19: 576-577, 1943.

27. Alexander, F. General principles, objectives and preliminary results. *In* The influence of psychologic factors upon gastro-intestinal disturbances: a symposium: a report upon research carried on at the Chicago Institute for Psychoanalysis. Psychoanalytic Quart., 3: 501-588, 1934.

28. Alexander, F. Emotional factors in essential hypertension. Psychosom. Med., 1: 173-179, 1939.

29. Alexander, F. Psychoanalytic study of a case of essential hypertension. Psychosom. Med., 1: 139-152, 1939.

30. American Child Health Association. A health survey of 86 cities. New York, 1925. 158 p.

31. American Dietetic Association. Selected list of references on national food patterns and recipes. June 1944. 21 p.

32. Anderson, J. E., and Smith, A. H. Relation of performance to age and nutritive condition in the white rat. J. Comp. Psych., 13: 409-446, 1932.

33. Angyal, A. Disgust and related aversions. J. Abn. and Soc. Psych., 36: 393-412, 1941.

34. Ashton, E. H. A sociological sketch of Sotho diet. School of Africa Studies, Univ. of Capetown. Tr. Royal Soc. So. Africa, 27: 147-214, 1939.

35. Atwater, W. O., and Woods, C. D. Dietary studies with reference to food of the Negro in Alabama in 1895 and 1896. U. S. Dept. of Agr., Off. of Exp. Sta., Bull. 38, 1897.

B

36. Bailey, F. L. Navaho foods and cooking methods. Am. Anthrop., 42: 270-290, 1940.

37. Bakwin, H. Malnutrition and mental disease in children. Nervous Child, 3: 160-161, 1944.

38. Balken, E. R., and Maurer, S. Variations in psychological measurements associated with increased vitamin B complex feeding in young children. J. Exp. Psych., 17: 85-92, 1934.

39. Balken, E. R., Maurer, S., and Falstein, E. I. Variations in psychological measurements associated with increased feeding of vitamins A, D, B_1 and B_2 with iron in dementia præcox. J. Comp. Psych., 21: 387-403, 1936.

40. Bash, K. W. Contribution to a theory of the hunger drive. J. Comp. Psych., 28: 137-160, 1939.

41. Bash, K. W. Possible organic basis for hunger drive. J. Comp. Psych., 28: 109-135, 1939.

42. Bateson, G. The frustration-aggression hypothesis and culture. Psych. Rev., 48: 350-355, 1941.

43. Bateson, G. Social planning and the concept of "deutero-learning." *In* Science, Philosophy, and Religion, Second Symp. New York, Conf. on Sci., Phil., and Rel., p. 81-97, 1942.

44. Bayer, E. Beitrage zur Zweikomponenten-theorie des Hungers. Zsch. f. Psych., 112: 1-53, 1929.

45. Bayer, L. M. The diet of adolescent girls, with special reference to nutritional status and dental caries. J. Pediat., 16: 56-68, 1940.

---

* Part of this bibliography was prepared initially for the Committee on Food Habits by Herbert Passin.

46. Bayroff, A. G. The experimental social behavior of animals. I. The effect of early isolation of white rats on their later reactions to other white rats as measured by two periods of free choices. J. Comp. Psych., 21: 67-81, 1936.
47. Bavelas, A. Group decision: paper read before a meeting of the S.P.S.S.I., 1943.
48. Bazore, K. Hawaiian and Pacific foods. New York, M. Barrows & Co., 1940. 286 p.
49. Beadles, J. R., Braman, W. W., and Mitchell, H. H. The cystine deficiency of the proteins of garden peas and of potatoes. J. Biol. Chem., 88: 615-622, 1930.
50. Beals, R. L., and Hatcher, E. Diet of a Tarascan village. América Indigena. 3: 295-304, 1943.
51. Bejarano, J. Alimentación y nutrición en Colómbia. 2a ed. Bogota, Editorial Cromos, 1940. 170 p.
52. Benedict, F. G., Miles, W. R., Roth, P., and Smith, H. M. Human vitality and efficiency under prolonged restricted diet. Carnegie Inst., Wash. Pub. 280, 1919.
53. Benedict, F. G., and Steggerda, M. The food of the present-day Maya Indians of Yucatan. Carnegie Inst., Wash. Pub. 456, p. 155-188, 1937.
54. Benet, S. M., and Joffe, N. F. Some Central European food patterns and their relationship to wartime problems of food and nutrition. Polish food patterns. Comm. on Food Habits, Nat. Res. Council. February 1943. 14 p. Mimeographed.
55. Bennett, J. W., Passin, H., and Smith, H. Food and culture in Southern Illinois: a preliminary report. Am. Soc. Rev., 7: 645-660, 1942.
56. Bennett, J. W. Food and social status in a rural society. Am. Soc. Rev., 8: 561-569, 1943.
57. Bennett, J. W. Some problems of status and solidarity in a rural society. Rural Soc., 8: 396-408, 1943.

See also Nos. 464, 465.

J. W. Bennett made an extensive anthropological study of food habits and the process of cultural change in Southern Illinois. See "The Problem of Changing Food Habits"[6] for summary of work.

58. Berkman, C. Mother-child relationships in cases involving difficulties in eating. Smith Coll. Stud. Soc. Work. 10: 105-106, 1939.
59. Bernhardt, K. S. The effect of vitamin B deficiency during nursing on subsequent learning in the rat. J. Comp. Psych., 17: 123-148, 1934.
60. Bernhardt, K. S. (1) Protein deficiency and learning in rats. (2) Phosphorus and iron deficiencies and learning in the rat. (3) Vitamin A deficiency and learning in the rat. J. Comp. Psych., 22: 269-278, 1936.
61. Bernhardt, K. S., and Herbert, R. A further study of vitamin B deficiency and learning with rats. J. Comp. Psych., 24: 263-267, 1937.
62. Biel, W. C. The effect of early inanition upon maze learning in the albino rat. Comp. Psych. Monogr., vol. 15, no. 2, 1938. 33 p.
63. Biel, W. C., and Wickens, D. D. The effects of vitamin B_1 deficiency on the conditioning of eyelid responses in the rat. J. Comp. Psych., 32: 329-340, 1941.
64. Bierens de Haan, J. A., and Heubel, F. Über Futtervorliebe bei Affen und die Bestimmung ihrer Grösse und Stärke. (Food preference in apes and the determination of its extent and strength.) Z. Morph. Ökol. Tiere, 34: 89-120, 1939.
65. Binger, C. A. A word to teachers about eating habits. Understanding the Child, 11: 3-6, 1942.
66. Blackstone, J. H., and Inman, B. T. Food habits of consumer groups in small towns of Alabama that affect farmers' markets. Ala. Agr. Exp. Sta. Bull. 252, 1942. 68 p.
67. Blanchard, M. A. School progress of well-nourished and undernourished children. J. Home Econ., 16: 645-646, 1924.
68. Blatz, W. E. A study of eating habits in a nursery school. *In* Bott, E. A., Blatz, W. E., Chant, N., and Bott, H. Observation and training of the fundamental habits in young children. Genet. Psych. Monogr., 4: 89-115, 1928.

69. Boalt, C., and Zotterman, Y. Rations and food consumption in Sweden during 1942-43. Nature, 152: 635-636, 1943.
70. Boas, F. Ethnology of the Kwakiutl. 35th Rept. of the Bur. of Am. Ethnology, p. 305-601, 1913-1914.
71. Boggs, E. G. Nutrition of 50 colored families in Chicago. Univ. of Chicago, 1929. M. A. thesis.
72. Bonser, H. J., and Tontz, R. L.. Food consumption by farm families near Douglas Reservoir. Tenn. Agr. Exp. Sta., Agr. Econ. and Rural Sociol. Dept. Monogr. 160, 1943. 44 p.
73. Boots, J. L. A preliminary study of the diet and customs of the Korean people with relation to their oral conditions. Korea, J. Severance Union Med. Coll., 3: 35-62, 1935.
74. Borsook, H., Alpert, E., and Keighley, G. L. Nutritional status of aircraft workers in Southern California. Milbank Mem. Fund Quart., 21: 115-157, 1943.
75. Borsook, H., and Halverson, W. L. Nutrition and health in Pasadena. Am. J. Pub. Health, 30: 895-900, 1940.
76. Bousfield, W. A. Certain quantitative aspects of chickens' behavior towards food. Am. J. Psych., 46: 456-458, 1934.
77. Bousfield, W. A. Quantitative indices of the effects of fasting on eating-behavior. J. Genet. Psych., 46: 476-479, 1935.
78. Bousfield, W. A. A study of experimentally induced shifts in food-preference. J. Genet. Psych., 61: 69-80, 1942.
79. Bousfield, W. A., and Elliott, M. H. The effect of fasting on the eating behavior of rats. J. Genet. Psych., 45: 227-237, 1934.
80. Bousfield, W. A., and Elliott, M. H. The experimental control of the hunger drive. J. Gen. Psych., 15: 327-334, 1936.
81. Bousfield, W. A., and Spear, E. Influence of hunger on the pecking responses of chickens. Am. J. Psych., 47: 482-484, 1935.
82. Bovee, D. L., and Downes, J. The influence of nutritional education in families of the Mulberry area of New York City. Milbank Mem. Fund Quart., 19: 121-146, 1941.
83. Boyd, G. R. The construction of an instrument for measuring attitudes toward desirable food practices. Coll. of Educ., Univ. of Kentucky, Bull. of Bur. of School Service, 16: 7-85, 1943.
84. Britton, V. Food consumption of 538 farm and 299 village families in Vermont. Vt. Agr. Exp. Sta. Bull. 474, 1941. 46 p.
85. Brockington, F. Further observations upon the influence of the growing family upon the diet in rural districts in Sussex. J. Hyg., 38: 547-557, 1938.
86. Brown, A. P. Food habits of Utah farm families. Utah Agr. Exp. Sta. Bull. 213, 1929. 20 p.
87. Brown, A. P. Diet as an index to living level in some Utah farm homes. Utah Acad. Sci. Proc., 8: 111-114, 1930-1931.
88. Brown, A. P. Food habits of rural school children in relation to their physical well-being. Utah Agr. Exp. Sta. Bull. 246, 1943. 52 p.
89. Browne, T. J. Nutrition and scholarship. N. Y. City Bull. of High Points, 10: 11-13, 1928.
90. Bruch, H. Dietary treatment of obesity in childhood. J. Am. Dietetic Assoc., 20: 361-364, 1944.
91. Bruch, H. Food and emotional security. Nervous Child, 3: 165-173, 1944.
92. Bruch, H., and Janis, M. Adjustment to dietary changes in various somatic disorders. *In* The problem of changing food habits, p. 66-73. *See No. 6.*
93. Bruch, H., and Touraine, G. Obesity in childhood. V. The family frame in obese children. Psychosom. Med., 2: 141-206, 1940.

H. Bruch has studied the psychosomatic aspects of food habits in reference to obesity in childhood.

94. Brues, C. T. Aberrant feeding behavior among insects and its bearing on the development of specialized food habits. Quart. Rev. Biol., 11:305-319, 1936.
95. Brush, A. L. Recent literature relative to the psychiatric aspects of gastrointestinal disorders. Psychosom. Med., 1: 423-428, 1939.
96. Bryson, B. E., Tucker, C., and Davis, H. J. A study of the diets of home demonstration club members' families in twenty-seven parishes of Louisiana. La. Agr. Exp. Sta. Bull. 356, 1942. 23 p.
97. Buck, P. H. Samoan material culture. Hawaii, Bernice P. Bishop Mus., 1930. 724 p.
98. Bunzel, R. The role of alcoholism in two Central American cultures. Psychiatry, 3: 361-387, 1940.
99. Burdette, R. F., and Walker, W. P. Where Frederick and Salisbury, Md. get their food supplies. Md. Agr. Exp. Sta. Bull. A 11, p. 313-331, 1942.
100. Byrd, H. M. Ways of living in 100 families in Harlem in 1932. New York, Teachers Coll., 1934. Unpublished M. A. thesis.

C

101. Campbell, E. H. The effect of nursery school training upon the later food habits of the child. Child Developm., 4: 329-345, 1933.
102. Cannon, W. B. Hunger and thirst. *In* Murchison, C. A handbook of general experimental psychology. Worcester, Clark Univ. Press, 1934. Chap. 5.
103. Carr, L. G. Survival foods of the American aborigines. J. Am. Dietetic Assoc., 19: 845-847, 1943.
104. Cassel, B. Jewish dietary laws and food customs. Pub. Health Nursing, 32: 682-687, 1940.
105. Castellanos, F. E. Valor diétetico de un menu tipico cubano. Rev. Méd.-quirúrg. de Oriente, 4: 12-16, 1943.
106. Castetter, E. F. Uncultivated native plants used as sources of food. Albuquerque, Univ. of New Mex., Bull. 266, 1935.
107. Castetter, E. F., and Bell, W. H. Pima and Papago Indian agriculture. New Mex. Quart. Rev., vol. 16, 1943. 245 p.
108. Castetter, E. F., and Opler, M. E. The ethnobiology of the chiricahua and mescalero Apache. A. The use of plants for foods, beverages and narcotics. Univ. of New Mex. Bull., Ethnobiological Studies in the American Southwest III, 1936.
109. Castro, J. d. Fisiología dos Tabús. Río de Janeiro: a. Edicão. Oficina Grafica Manúa Ltda., 1941. 63 p.
110. Cathcart, E. P., and Murray, A. M. T. A study in nutrition; an inquiry into the diet of 154 families of St. Andrews. London, Privy Council, Med. Res. Council. Spec. Rept. Series No. 151, H. M. Stationery Off., 1931. 60 p.
111. Cathcart, E. P., and Murray, A. M. T. Studies in nutrition: an inquiry into the diet of families in Cardiff and Reading. London, H. M. Stationery Off., 1932. 28 p.
112. Cathcart, E. P., and Murray, A. M. T. A dietary survey in terms of the actual foodstuffs consumed. London, Privy Council, Med. Res. Council. Spec. Rept. Series No. 218, H. M. Stationery Off., 1936. 56 p.
113. Cathcart, E. P., Murray, A. M. T., and Beveridge, J. B. An inquiry into the diet of families in the highlands and islands of Scotland. Studies in nutrition. London, Privy Council, Med. Res. Council. Spec. Rept. Series No. 242, H. M. Stationery Off., 1940. 37 p.
114. Chaney, L. B., and McGraw, M. B. A study of 125 neonates. Bull. of Neurolog. Inst., 2: 1-56, 1932.
115. Chaplin, J. P. The equilibrium between carbohydrate and protein appetites as studied by the preference method under conditions of group self-selection maintenance. Psych. Bull., 39: 590, 1942.
116. Charles, J. A. A study of the diets of 69 working class families in Newcastle upon Tyne. Newcastle upon Tyne, Health Dept., Town Hall, December 1936. 45 p.

117. Cheng, L. T., and Ku, H. C. A dietary study of the middle-class Chinese and Mohammedans in Sungpan. Sci. Soc. China, Biol. Lab. Contrib., Zool. Ser., 13: 91-99, 1939.

118. Cheng, L. T., Tao, H., and Chu, C. K. A study of the winter dietary in Nanking. Sci. Soc. China, Biol. Lab. Contrib., Zool. Ser., 10: 291-302, 1935.

119. Childs, A. Some dietary studies of Poles, Mexicans, Italians and Negroes. Child Health Bull., 9: 84-91, 1933.

120. Ciccarelli, E. Emotional factors operating as primary causes of malnutrition. Understanding the Child, 11: 7-10, 1942.

121. City of New York. Department of Welfare. Characteristics of the Italian dietary. 1938.

122. Clapp, E. V. W. An analysis of the food consumption of 119 farm families in Connecticut, 1936. Univ. of Chicago. M. S. thesis.

123. Clark, F. Le G. The school child and the school canteen. Hertford, Herts., Eng., Stephen Austin & Sons, Ltd., 1942. 35 p.

124. Clark, F. Le G. The communal restaurant, a study of the place of civic restaurants in the life of the community. London Council of Soc. Service, p. 3-36, 1943.

125. Clark, F. Le G. The school child's taste in vegetables. Hertford, Herts., Eng., Stephen Austin & Sons, Ltd., 1943. 14 p.

126. Clark, F. Le G. Food habits and how to change them. Lancet, 247: 53-55, 1944.

127. Clark, F. Le G., and McKay, H. S. Allocation of food within the family circle. Harpenden, Herts., Eng., 1943. 15 p. Mimeographed.

F. Le G. Clark has developed a method of using children's and adults' essays and responses to planned questionnaires and interviews to indicate qualitative as well as quantitative aspects of attitudes toward a given problem.

128. Clark, W. G., and Clausen, D. F. Dietary "self-selection" and appetites of untreated and treated adrenalectomized rats. Am. J. Physiol., 139: 70-79, 1943.

129. Clayton, M. M. The relation of dietary habits and food resources of Maine people to their state of nutrition with respect to vitamin C. Maine Agr. Exp. Sta. Bull. 397, p. 724-726, 1939.

130. Clayton, M. M. A study of the food habits and nutritional status of children in selected communities in Maine. Maine Agr. Exp. Sta. Bull. 405, p. 431-456, 1941. See Bull. 401, 1940, by the same author.

131. Clayton, M. M. Food habits and physical condition of grade school children in Newport, Maine. Maine Agr. Exp. Sta. Bull. In press.

132. Cluver, E. H. Nutrition of the Union population. J. Roy. Sanit. Inst., 59: 99-107, 1938.

133. Coco, L. C., Moore, M., Goldsmith, G. A., Lucas, G. P., and Davis, H. J. A study of the adequacy of diets consumed by grade-school and high-school students in Louisiana. La. Agr. Exp. Sta. Bull. 360, 1943. 10 p.

134. Coffin, M. The sources of the food used by Maryland farmers. Md. Agr. Exp. Sta. Bull. 346, p. 495-515, 1933.

135. Cohen, B. G. Emotions and food therapy. Boston, Simmons College, 1939. M. A. thesis.

136. Committee on Food Habits. The relationship between food habits and problems of wartime emergency feeding. The Committee, May 1942. 9 p. Mimeographed.

137. Committee on Food Habits. A study of some personality factors in block leaders in low income groups. The Committee, June 1943. 20 p. Mimeographed.

138. Committee on Food Habits. Contributions from the field of child development. *In* The problem of changing food habits, p. 149-157. *See No. 6.*

139. Committee on Food Habits. Contributions from the field of market research. *In* The problem of changing food habits, p. 141-148. *See No. 6.*

140. Committee on Food Habits. Feeding liberated countries and nutrition education. *In* The problem of changing food habits, p. 162-164. *See No. 6.*
141. Committee on Food Habits. Impact of the war on local food habits. *In* The problem of changing food habits, p. 168-169. *See No. 6.*
142. Committee on Food Habits. Local food sufficiency. *In* The problem of changing food habits, p. 159. *See No. 6.*
143. Committee on Food Habits. Problems of food supply, food habits, and nutrition in China. *In* The problem of changing food habits, p. 165-167. *See No. 6.*
144. Committee on Food Habits. Rationing and morale. *In* The problem of changing food habits, p. 160-161. *See No. 6.*
145. Committee on Food Habits. Research in the field of food habits. *In* The problem of changing food habits, p. 127-140. *See No. 6.*
146. Committee on Food Habits. Supplementing the role of the nutritionist at the household level. *In* The problem of changing food habits, p. 158. *See No. 6.*
147. Committee on Food Habits. The wartime role of the nutritionist. *In* The problem of changing food habits, p. 158. *See No. 6.*
148. Committee on Food Habits. Problems of food distribution in countries differently affected by the war. The Committee, December 1943. 11 p. Mimeographed.
149. Committee on Food Habits. Acute food problems under war conditions. The Committee, February 1944. 30 p. Mimeographed.
150. Committee on Food Habits. Research on appetite levels. The Committee, February 1944. 54 p. Mimeographed.
151. Committee on Food Habits. Application of anthropology to problems of nutrition and population. The Committee, April 1944. 37 p. Mimeographed.
152. Common Council for American Unity. What's cooking in your neighbor's pot. New York, N. Y. Mimeographed, 1944.
153. Conrad, A. The attitude toward food. Am. J. Orthopsychiat., 7: 360-367, 1937.
154. Contribution to the study of nutritional status in rural and urban populations. Pa. St. Coll. Bull., vol. 36, no. 52, 1942. 60 p.
    I. Mack, P. B., Smith, J. M., Logan, C. H., O'Brien, H. T., Baur, M., Stewart, A. H., and Dodds, P. Résumé of Pennsylvania human nutrition studies from 1935 to 1941.
    II. Mack, P. B., Urbach, C., Smith, J. M., Rose, E. K., Logan, C. H., O'Brien, A. T., Baur, M., Freeman, L. V., Bleil, D. R., Stewart, A. H., and Dodds, P. Preliminary report on 1,362 metropolitan school children, 1941-1942.
155. Cook, S. F. The mechanism and extent of dietary adaptation among certain groups and Nevada Indians. Berkeley, Univ. of Calif. Press, 1941. 59 p.
156. Cowles, M. L. A study of winter food consumption in Wisconsin farm families. J. Am. Dietetic Assoc., 11: 322-330, 1935.
157. Cowles, M. L. Food consumption of Wisconsin relief families. Wisc. Agr. Exp. Sta., Stencil Bull. February 1937. 27 p.
158. Culwick, G. M. Nutrition work in British African colonies since 1939. Africa, 14: 24-26, 1943.
159. Cummings, R. O. The American and his food. Univ. of Chicago Press, 1941. 291 p.

    Systematic historical account of food habits in U. S., with particular reference to social and technological influences on the diet, and to the development of the national nutrition program.

160. Cushing, F. H. Zuni breadstuff. Ind. Notes and Monogr., vol. 8, 1920. New York, Mus. of the Am. Ind., Heye Found.
161. Cussler, M. T. Cultural sanctions of the food pattern in the rural Southeast. Radcliffe College, 1943. Ph. D. thesis.
162. Cussler, M. T., and de Give, M. L. Interrelations between the cultural pattern and nutrition. U. S. Dept. of Agr., Ext. Serv. Circ. 366, August 1941.

163. Cussler, M. T., and de Give, M. L. Let's look it in the eye. U. S. Dept. of Agr., Consumers' Guide, March 15, 1942.

164. Cussler, M. T., and de Give, M. L. The effect of human relations on food habits in the rural Southeast. Applied Anthrop., 1: 13-18, 1942.
See also No. 175.

165. Cussler, M. T., and de Give, M. L. Foods and nutrition in our rural Southeast. J. Home Econ., 35: 280-282, 1943.

166. Cussler, M. T., and de Give, M. L. Outline of studies on food habits in rural Southeast. *In* The problem of changing food habits, p. 109-112. *See No. 6.*

M. T. Cussler made a comprehensive sociological field study of food habits in three localities in the Southeast. See "The Problem of Changing Food Habits," [6] for summary of work.

D

167. D'Agostino, M. A. Diet of the Italian people. Detroit Dept. of Public Welfare.

168. Dallenbach, J. W., and Dallenbach, K. M. The effects of bitter-adaptation on sensitivity to the other taste-qualities. Am. J. Psych., 61: 21-31, 1943.

169. Daver, M. B. Observations on dietary habits and nutritional conditions in Hyderabad State. Indian Med. Assoc. J., 12: 42-45, 1942.

170. Davies, E. S. The food consumption of rural school children. Mass. Agr. Exp. Sta. Bull. 241, p. 97-147, 1928.

171. Davis, C. M. Self-selection of diet by newly weaned infants. Am. J. Dis. Child., 36: 651-679, 1928.

172. Davis, C. M. Choice of formulas made by three infants throughout the nursing period. Am. J. Dis. Child., 50: 385-394, 1935.

173. Davis, C. M. Self-selection of food by children. Am. J. Nursing, 35: 403-410, 1935.

174. de Give, M. L. Social interrelations and food habits in the rural Southeast. Radcliffe College, 1943. Ph. D. thesis.
See also Nos. 162-166.

M. L. de Give made a comprehensive sociological field study of food habits in three localities in the Southeast. See "The Problem of Changing Food Habits," [6] for summary of work.

175. de Give, M. L., and Cussler, M. T. Bibliography and notes on German food patterns. Comm. on Food Habits, Nat. Res. Council. February 1944. 19 p. Mimeographed.

176. Descartes, S. L., Pacheco, S. D., and Noguera, J. R. Food consumption studies in Puerto Rico. Puerto Rico Univ., Agr. Exp. Sta. Bull. 59, 1941. 76 p.

177. Desmond, A., and Baumgartner, L. Health education in nutrition. Am. J. Pub. Health, 34: 967-973, 1944.

178. Deutsch, F. Prophylactic aspects of the malnutrition problem. Nervous Child, 3: 195-215, 1944.

179. Deutsch, F. The choice of organ in organ neuroses. Int. J. Psychoanalysis, 20: 252-262, 1939.

180. Dickins, D. A study of food habits of people in two contrasting areas of Mississippi. Miss. Agr. Exp. Sta. Bull. 245, 1927. 52 p.

181. Dickins, D. A nutrition investigation of Negro tenants in the Yazoo-Mississippi Delta. Miss. Agr. Exp. Sta. Bull. 254, 1928. 52 p.

182. Dickins, D. Home production of food for family consumption. Miss. Farm Res., 4: 1-8, 1941.

183. Dickins, D. Improving levels of living of tenant families. Miss. Agr. Exp. Sta. Bull. 365, January 1942. 18 p.

184. Dickins, D. Food preparation of owner and cropper farm families in the Shortleaf Pine Area of Mississippi. Social Forces, 22: 56-63, 1943.

185. Dickins, D. Some effects of a white cornmeal shortage. Miss. Agr. Exp. Sta. Paper No. 88, New Series, 1944.

186. Dickins, D. Vegetable preferences of white and Negro children. Miss. Farm Res., vol. 7, no. 9, 1944. 7 p.

D. Dickins has conducted studies within the framework of a state experiment station with particular reference to the sociological factors involved in food consumption.

187. Dickins, D., and Ford, R. N. Geophagy (dirt eating) among Mississippi Negro school children. Am. Soc. Rev., 7: 59-65, 1942.

188. Dietary thiamin levels and deficiency symptoms. Nutrition Rev., 2:328-330, 1944.

189. Dodd, S. C. A controlled experiment on rural hygiene in Syria: a study in the measurement of rural culture patterns and of social forces. Am. Univ. of Beirut, Soc. Sci. Studies, vol. 7, 1936. 336 p.

190. Donath, W. F., Ochse, S. S., and Terra, Sr. G. J. A. Geld-en Producten-Huishouding, Volksvoeding en-Gezondheid in Koetowinangoen. Dept. van Economische Zaken, Archipel Drukkerij, Buitenzoorg, 1934. (The function of money and products in relation to native diet and physical condition in Koetowinangoen (Java). Tr. by A. A. Hamilton.)

191. Donelson, E., Nelson, P. M., Pittman, M. S., Leverton, R. M., McKay, H., Kinsman, G. M., Armstrong, W., and Reynolds, M. S. The nutritional status of midwestern college women. To appear in J. Am. Dietetic Assoc., March 1945.

192. Dorcus, R. M. Food habits: their origin and control. J. Am. Dietetic Assoc., 18: 738-740, 1942.

193. Dorcus, R. M., and Leeds, J. The relation between subjective estimates of the quality of certain food products and their cost. Am. J. Psych., 55: 261-264, 1942.

194. Dove, W. F. A study of the causes of nutritional deficiency diseases in the livestock and inhabitants of Maine with possible corrective methods secured from the utilization of Maine fishery products and the production of superior foods. Maine Agr. Exp. Sta. Bull. 375, p. 191-284, 1934.

195. Dove, W. F. A study of individuality in the nutritive instincts and of the causes and effects of variation in the selection of food. Am. Nat., 69: 469-544, 1935.

196. Dove, W. F. The nutritive instincts and food habits of superior individuals as guides to the nutritional requirements of the group. Proc. Am. Soc. Animal Produc., p. 243-247, November 27-28, 1936.

197. Dove, W. F. The needs of superior individuals as guides to group ascendance: an experimental approach to the problem of "optimum environment." J. Hered., 30: 157-163, 1939.

198. Dove, W. F. A study of the relation of man and animals to the environment. Maine Agr. Exp. Sta. Bull. Part I, Bull. 380: 187-204, 1935. II, Bull. 387: 197-201, 1937. III, Bull. 391: 263-267, 1938. IV, Bull. 397: 726-773, 1939. V, Bull. 400: 235-248, 1940. VI, Bull. 405: 441-458, 1941.

A series of papers discussing the climate-soil-plant-animal-man interrelationship, the relationship between nutritional deficiency diseases and food production, the use of food preference as a guide to the selection of foods, the genetic improvement of the vitamin content of preferred foods, the use of superior individuals in determining the optimum selection of foods, and the bioecological and bioeconomic applications of food production for use.

199. Dove, W. F. Appetite levels of food consumption: a technique for measuring foods in terms of psychological and nutritional values combined. Human Biol., 15: 199-220, 1943.

200. Dove, W. F. On the linear arrangement of palatability of natural foods with an example of varietal preference in Leguminosae and Cruciferae by a new, rapid laboratory method. J. Nutrition, 25: 447-462, 1943.

201. Dove, W. F. The relative nature of human preference: with an example in the palatability of different varieties of sweet corn. J. Comp. Psych., 35: 219-226, 1943.

202. Dove, W. F. Basic foods and the nutrition of populations: on the use of appetite levels of food consumption for ascertaining the basic foods required for the optimum nutrition of populations and appropriate to different regions or countries. *In* Research on appetite levels. Comm. on Food Habits, Nat. Res. Council, February 1944, p. 17-46. Mimeographed.

Starting from a biological background, has developed a survey technique for classifying foods according to familiarity of the people in a given region with them, preference value, and nutritive value, and, after a consideration of these factors, developing a plan for optimum nutrition by 1) improving genetically the nutritive value of the preferred food, and 2) relating the food needs and the food supply in a given region.

203. Downes, J. A study of food habits of tuberculous families in a Harlem area of New York City. Milbank Mem. Fund Quart., 21: 164-181, 1943.
204. Downes, J., and Baranovsky, A. Food habits of families in the Eastern Health District of Baltimore in the winter and spring of 1943. Milbank Mem. Fund Quart., 23: 161-192, 1944.
205. Drake, P., and Lamb, M. W. Study of the dietary and food practices of 63 families in Lubbock, Texas. J. Am. Dietetic Assoc., 20: 528-529, 1944.
206. Drummond, J. C., and Wilbraham, A. The Englishman's food. London, J. C. Cape, 1939. 574 p.
207. Dubois, C. Attitudes toward food and hunger in Alor. *In* Spier, L., and others, ed. Language, culture, and personality: essays in memory of Edward Sapir. Menashá, Wis., Sapir Memorial Pub. Fund, p. 272-281, 1941.
208. Dunbar, H. F. Emotions and bodily changes. 2nd ed. New York, Columbia Univ. Press, 1938. 601 p.
209. Dunbar, H. F. Psychosomatic diagnosis. New York, Paul Hoeber, 1943. 741 p.
210. Dunbar, H. F., Wolfe, T. P., Tauber, E., Brush, A. L., with assistance of Rioch, J. McK., and Coffin, M. The psychic component of the disease process (including convalescence) in cardiac, diabetic and fracture patients. Part II. Am. J. Psychiat., 95: 1310-1342, 1939.
211. Duncher, K. Experimental modification of children's food preferences through social suggestion. J. Abn. and Soc. Psych., 33: 489-507, 1938.
212. Dunshee, M. E. A study of factors affecting the amount and kind of food eaten by nursery school children. Child Developm., 2: 163-183, 1931.

E

213. Ebbs, J. H., Brown, A., Tisdall, F. F., Moyle, W. J., and Bell, M. Influence of improved prenatal nutrition upon the infant. Canad. Med. Assoc. J., 46: 6-8, 1942.
214. Ebbs, J. H., Tisdall, F. F., and Scott, W. A. The influence of prenatal diet on the mother and child. J. Nutrition, 22: 515-526, 1941.
215. Eggan, F., and Pijoan, M. Some problems in the study of food and nutrition. América Indigena, 3: 9-22, 1943.
216. Eliot, A. A. Eating habits in relation to personality development of two- and three-year old children. Genet. Psych. Monogr., 13: 399-481, 1933.
217. Elliott, M. H. The effect of change of reward on the maze performance of rats. Univ. Calif. Pub. Psych., 4: 19-30, 1928.
218. Engel-Frisch, G. A study of the effects of odd-shifts upon the food habits of war workers. *In* The problem of changing food habits, p. 82-84. *See No. 6.*
219. England, N. J. The relation between health and intelligence in school children. Holland (Lincolnshire) County. J. Hyg., 36: 74-94, 1936.
220. Erickson, I. The eating habits of the psychiatric patient. Bull. Menninger Clin., 2: 54-60, 1938.
221. Erickson, M. H. Hypnotic investigation of psychosomatic phenomena: III. A controlled experimental use of hypnotic regression in the therapy of an acquired food tolerance. Psychosom. Med., 5: 67-70, 1943.
222. Evvard, J. M. Is the appetite of swine a reliable indication of physiological needs? Proc. Iowa Acad. Sci., 22: 375-403, 1915.

F

223. Family living studies. Hawaii Agr. Exp. Sta. Bien. Rept., p. 136, 1941-1942.

224. Fearing, F., and Ross, G. Behavior factors affecting body temperature in pigeons. II. General level of activity as modified by deprivation and ingestion of food with particular reference to the "hunger drive." J. Comp. Psych., 22: 231-239, 1936.

225. Ferguson, H. H. Food industry: the investigation of consumers' taste preferences. Human Factor, 11: 399-405, 1937.

226. Festinger, L. Development of differential appetite in the rat. J. Exp. Psych., 32: 226-234, 1943.

227. Festinger, L. Effect of container on food preferences. Comm. on Food Habits, Nat. Res. Council. March 1944. 23 p. Mimeographed.

228. Finan, J. L., and Taylor, L. F. Quantitative studies in motivation. I. Strength of conditioning in rats under varying degrees of hunger. J. Comp. Psych., 29: 119-134, 1940.

229. Firth, R. Sociological study of native diet. Africa, 7: 401-414, 1934.

230. Firth, R. Housekeeping among Malay peasants. London Sch. of Econ. and Pol. Sci., Monogr. on Soc. Anthrop., no. 7, 1943. 198 p.

231. Fitts, P. M. Some relationships between the hunger drive and experimental extinction. Psych. Bull., 33: 600-601, 1936.

232. Fitts, P. M. Factors influencing the rate of eating of the white rat. Psych. Bull., 34: 539, 1937.

233. Fortes, M., and Fortes, S. L. Food in the domestic economy of the Tallensi. Africa, 9: 237-276, 1936.

234. Frank, M. The effect of a rickets-producing diet on the learning ability of white rats. J. Comp. Psych., 13: 81-105, 1932.

235. Franke, K. W., and Potter, V. R. The ability of rats to discriminate between diets of varying degrees of toxicity. Science, 83: 330-332, 1936.

236. Frayser, M. E. Children of preschool age in selected areas of South Carolina. S. C. Agr. Exp. Sta. Bull. 260, 1929. 80 p.

237. Frayser, M. E., and Moser, A. M. The diet of school children in relation to their health. S. C. Agr. Exp. Sta. Bull. 268, 1930. 64 p.

238. Fremont-Smith, F. The influence of emotional factors upon physiological and pathological processes. Bull. N. Y. Acad. Med., 15: 560-569, 1939.

239. French, R. L. A method and apparatus for demonstrating olfactory sensitivity in the rat. J. Comp. Psych., 29: 307-313, 1940.

240. Friesenhahn, H. Untersuchungen über die Appetitsrichtungen und den Speiseabscheu bei Schulkindern. Zsch. f. Kinderforsch., 40: 1-54, 1932.

241. Fritz, M. F. Maze performance of the white rat in relation to unfavorable salt mixture and vitamin B deficiency. J. Comp. Psych., 13: 365-390, 1932.

242. Fritz, M. F. A classified bibliography on psychodietetics. Psych. Monogr., vol. 46, no. 206, 1934. 53 p.

Classifies references and discussion according to abnormal physical and mental conditions.

243. Fritz, M. F. The effect of diet on intelligence and learning. Psych. Bull., 32: 355-363, 1935.

244. Fuller, R. W. The effect of home produced foods upon the eating habits of preschool children in Henderson County, Texas. Prairie View Sta. College, 1942. M. A. thesis.

245. Furnas, C. C. and S. V. Man, bread, and destiny: the story of man's food. New York, Reynal & Hitchcock, 1937. 364 p.

G

246. Gamio, M. An analysis of social processes and the obstacles to agricultural progress in Mexico. Rural Soc., 2: 143-147, 1937.

247. Gangulee, N. Bibliography of nutrition in India. London, Oxford Univ. Press, 1940. 79 p.

248. Gantt, W. H. Extension of a conflict based upon foods to other physiological systems and its reciprocal relations with sexual functions. Am. J. Physiol., 123: 73-74, 1938.

249. Gaston, H. P. Consumer demand for apples in Michigan. Mich. Agr. Exp. Sta. Spec. Bull. 209, 1931. 50 p.

250. Gauger, M. E. The modifiability of response to taste stimuli in the preschool child. Teach. Coll. Contrib. Educ., no. 348, 1929. 53 p.

251. Gilbert, F. D. New Mexican diets. J. Home Econ., 34: 668-669, 1942.

252. Gillett, L., and Rice, P. Influence of education on the food habits of some New York City families. N. Y. Assoc. for Improving the Condition of the Poor, 1931. 48 p.

253. Gillin, J. Houses, food, and the contact of cultures in a Guatemalan town. Acta Americana, vol. 1, p. 344-359, 1943.

254. Gold, Leah. Changing student food habits through school programs. J. School Health, 15: 7-14, 1945.

255. Govande, G. K. A statistical examination of taste differences in bajra varieties. Current Sci., vol. 10, p. 179-180, 1941.

256. Graham, J. C. Individuality of pullets in balancing the ration. Poultry Sci., 13: 34-39, 1934.

257. Graham, W. R. Can we learn anything from a free choice of feeds as expressed by chickens? Poultry Sci., 11: 365-366, 1932.

258. Graper, F. M., and Park, E. W. The effect of improved feeding on the physical and mental development of under-nourished and backward children. J. Home Econ., 15: 627-632, 1923.

259. Graubard, M. Man's food, its rhyme and reason. New York, Macmillan, 1943. 213 p.

Illustrated by examples of the "non-rational" nature of traditional food practices as a comment on the history of thought and the need for the application of nutritional science.

260. Greenwood, M. L., and Lonsinger, B. N. Food intake of college women: caloric intake and energy requirement. J. Am. Dietetic Assoc., 20: 524-527, 1944. See also 20: 671-675, 1944.

261. Gregory, E., Jackson, C., and McLaughlin, E. C. G. New Zealand dietary studies. I. Dietary studies of one hundred and seventy families of varying occupations. N. Z. Med. J., 42: 64-72, 1943.

262. Grindley, G. C. Experiments on the influence of the amount of reward on learning in young chickens. Brit. J. Psych., 20: 173-180, 1929.

263. Grisby, N. E., McBryde, L. C., and Davis, H. J. A study of the adequacy of diets of Farm Security Administration families in Louisiana. Baton Rouge, La. St. Univ., Coll. of Agr., Nutr. Lab., September 1942. Mimeographed.

264. Gross, I. H. A survey of food habits in a Hungarian mining town. J. Home Econ., 17: 315-321, 1925.

265. Guhl, A. M., and Allee, W. C. Some measurable effects of social organization in flocks of hens. Physiol. Zool., 17: 320-347, 1944.

266. Guthe, C. E. History of the Committee on Food Habits. *In* The problem of changing food habits, p. 9-19. *See No. 6.*

267. Gutierrez, M., and Santos, F. O. The food consumption of 104 families in Paco District, Manila. Phil. J. Sci., 66: 397-416, 1938.

H

268. Haggard, H. W., and Greenberg, L. A. Between-meal feeding in industry: effects on the absenteeism and attitude of clerical employees. J. Am. Dietetic Assoc., 15: 435-439, 1939.

269. Hall, I. S., and Hall, C. S. A study of disliked and unfamiliar foods. J. Am. Dietetic Assoc., 15: 540-548, 1939.

270. Hammargren, S., and Porje, I. Changes in the symptom picture in three cases of acute psychosis after administration of vitamin B_1, pyrophosphate, and fumarate. Svenska Läkartidn., 37: 1893-1898, 1940.

271. Hardy, M. C., Spohn, A., Austin, G., McGiffert, S., Mohr, E., and Peterson, A. B. Nutritional and dietary inadequacies among city children from different socio-economic groups. J. Am. Dietetic Assoc., 19: 173-181, 1943.

272. Harlow, H. F. Food preferences of the albino rat. J. Genet. Psych., 41: 430-437, 1932.

273. Harlow, H. F. Social facilitation of feeding in the albino rat. J. Genet. Psych., 41: 211-221, 1932.

274. Harlow, H. F., and Yudin, H. C. Social behavior of primates. I. Social facilitation of feeding in the monkey and its relation to attitudes of ascendance and submission. J. Comp. Psych., 16: 171-185, 1933.

275. Harrell, R. F. Effect of added thiamine on learning. Teach. Coll. Contrib. Educ., no. 877, 1943. 55 p.

276. Harris, L. J., Clay, J., Hargreaves, F. J., and Ward, A. Appetite and choice of diet. The ability of the vitamin B deficient rat to discriminate between diets containing and lacking the vitamin. Proc. Roy. Soc. London, Series B, 113: 161-190, 1933.

277. Harris, R. S., Weeks, E., and Kinde, M. Effect of a supplementary food on the nutritional status of school children. J. Am. Dietetic Assoc., 19: 182-189, 1943.

278. Hausmann, M. F. The behavior of albino rats in choosing food and stimulants. J. Comp. Psych., 13: 279-309, 1932.

279. Hausmann, M. F. The behavior of albino rats in choosing foods. II. Differentiation between sugar and saccharin. J. Comp. Psych., 15: 419-428, 1933.

280. Hausmann, M. F. Tierexperimentelle Untersuchungen zur Erforschung der Bedürfnisse. Schweiz. Arch. Neurol. Psychiat., 34: 254-266, 1934.

281. Hawks, J. E. Preparation and composition of foods served in Chinese homes. J. Am. Dietetic Assoc., 12: 136-140, 1936.

282. Hawley, F., Pijoan, M., and Elkin, C. A. An inquiry into food economy and body economy in Zia Pueblo. Am. Anthrop., 45: 547-556, 1943.

283. Hellersberg, E. F. Food habits of adolescents in relation to their socio-psychological adjustment. In ms. form.

Working from the point of view of analytic psychology, has developed a questionnaire technique to be used with adolescents and their mothers, in which the food preference items are repeated for both groups and the other questions are rephrased appropriately for the mothers, but cover the same items of childhood behavior and habits as the questions given the adolescents.

284. Hellmann, E. Urban native food in Johannesburg. Africa, 9: 277-290, 1936.

285. Heron, W. T., and Skinner, B. F. Changes in hunger during starvation. Psych. Rec., 4: 51-60, 1937.

286. Hill, J. Infant feeding and personality disorders. A study of early feeding in its relation to emotional and digestive disorders. Psychiat. Quart., 11: 356-382, 1937.

287. Hiralal, R. B. Some notes about marriage, food, drink, and occupations of caste affecting social status in the central provinces. Man in India, 5: 56-68, 1925.

288. Hobson, A., and Schaars, M. A. Consumer preferences for cheese. Wisc. Agr. Exp. Sta. Res. Bull. 128, 1935. 48 p.

289. Hoelzel, F. An explanation of appetite. Am. J. Diges. Dis., 4: 71-76, 101-108, 1944.

290. Holden, F. A study of the effect of starvation upon behavior by means of the obstruction method. Comp. Psych. Monogr., vol. 3, 1925-1926. 45 p.

291. Hollen, E., and Mack, P. B. A study of the dietary status of school children of different national and racial backgrounds in an anthracite coal region of Pennsylvania. Chemistry Leaflet, Pa. St. Coll., vol. 17, no. 11, 1944.

292. Hollinger, M., and Roberts, L. J. Overcoming food dislikes: a study with evaporated milk. J. Home Econ., 21: 923-932, 1929.

293. Honigmann, John J. Foodways of the Fort Nelson Indians. 1943. 16 p. Ms. in Off. of Med. Services, Dept. of Indian Affairs, Ottawa, Can.

294. Howe, P. E. Can food habits be changed? *In* Food and life, p. 131-138. *See No. 24.*

295. Huenemann, R. L., and Turner, D. Methods of dietary investigation. J. Am. Dietetic Assoc., 18: 562-568, 1942.

296. Hunt, J. McV. Effect of feeding frustration in infancy upon adult hoarding in the white rat. Psych. Bull., 37: 487-488, 1940.

297. Hunt, J. McV. Effect of infant feeding-frustration upon adult hoarding in the albino rat. J. Abn. and Soc. Psych., 36: 338-360, 1941.

298. Hunter, G., and Pett, L. B. A dietary survey in Edmonton. Canad. Pub. Health J., 32: 259-265, 1941.

I

299. Internat. Inst. of African Languages and Cultures. The food and nutrition of African natives. Memorandum 13. London, Oxford Univ. Press, 1937.

Contains extensive bibliography of work in diet and nutrition done in Africa.

J

300. Jackson, P., and Schuck, C. Nutritional adequacy of foods purchased by college women on limited and more liberal food budgets. J. Am. Dietetic Assoc., 17: 784-789, 1941.

301. Jacob, H. E. Tr. by R. and C. Winston. Six thousand years of bread. New York, Doubleday, 1944. 399 p.

302. Jaffa, M. E. Nutrition investigations among fruitarians and Chinese at the California Agricultural Experiment Station. Calif. Agr. Exp. Sta. Bull. 107, 1899-1901. 43 p.

303. Jakway, I. Voluntary activity in the rat as related to intake of whole yeast. J. Comp. Psych., 26: 157-162, 1938.

304. Jelliffe, S. E. Sketches in psychosomatic medicine. Nerv. Ment. Dis. Monogr., no. 65, 1939.

305. Joffe, N. F. Some Central European food patterns and their relationship to wartime programs of food and nutrition. Comm. on Food Habits, Nat. Res. Council. January 1943. 3 p. Mimeographed.

306. Joffe, N. F. Some Central European food patterns and their relationship to wartime problems of food and nutrition. Hungarian food patterns. Comm. on Food Habits, Nat. Res. Council. February 1943. 10 p. Mimeographed.

307. Joffe, N. F. Food habits of selected subcultures in the United States. *In* The problem of changing food habits, p. 97-103. *See No. 6.*

308. Joffe, N. F. Tests of acceptability of emergency rations. *In* The problem of changing food habits, p. 104. *See No. 6.*
See also Nos. 54, 414, 449, 484.

309. Joffe, N. F., Janis, M., Shippee, E., and Woodward, P. Role of milk in American culture. Comm. on Food Habits, Nat. Res. Council. October 1943. 40 p. Mimeographed.

310. Joffe, N. F., and Walker, T. T. Some food patterns of Negroes in the United States of America and their relationship to wartime problems of food and nutrition. Comm. on Food Habits, Nat. Res. Council. April 1944. 50 p. Mimeographed.

N. F. Joffe has developed an anthropological technique for studying the food habits of nationality groups in this country and of other countries by use of informants and consultation of the literature. Also has developed a method of experimentally testing the acceptability of food.

311. Jukes, C. L. Selection of diet in chicks as influenced by vitamins and other factors. J. Comp. Psych., 26: 135-156, 1938.

K

312. Katz, D. Die Gesetz der Nahrungsaufnahme in ihrer grundsätzlichen Bedeutung für die Bedürfnispsychologie. (The laws of food intake in their fundamental significance for the psychology of need.) Indus. Psychotechn., 10: 28-29, 1933.
313. Katz, D. Some problems of human feeding in relation to industrial psychology. Human Factor, 9: 127-237, 1935.
314. Katz, D. A study of the taste of bread. Human Factor, 11: 210-217, 1937.
315. Kelly, H. T., and Sheppard, M. Dietary study of subjects from upper income groups. New Eng. J. Med., 228: 118-124, 1943.
316. Kephart, H. Our southern highlanders. New York, Macmillan, 1929. 469 p.
317. Keys, A. Physical performance in relation to diet. Fed. Proc., 2: 164-187, 1943.
318. Keys, A., Henschel, A., Taylor, H. L., Mickelsen, O., and Brozek, J. Absence of rapid deterioration in men doing hard physical work on a restricted intake of vitamins of the B complex. J. Nutrition, 27: 485-495, 1944.
319. King, A. A study of the Italian diet in a group of New Haven families. Yale University, 1935. M. A. thesis.
320. Kiss, P. V. Die Behandlung der Nerven-Krankheiten in Kindesalter durch Vitamin B_1. (The treatment of nervous diseases in childhood with vitamin B_1). Arch. Kinderheilk, 119: 182-193, 1940.
321. Kleiber, M., and Smith, A. H. Eating habits and fasting metabolism of rats. Proc. Soc. Exp. Biol., 45: 630-632, 1940.
322. Koch, A. M., and Warden, C. J. The influence of quantitative stunting on learning ability in mice. J. Genet. Psych., 48: 215-217, 1936.
323. Kon, S. K. The self-selection of food constituents by the rat. Biochem. J., 25: 473-481, 1931.
324. Koos, E. L. Food in the lives of our neighbors. New York, District Health Comm., Kips Bay-Yorkville Health Dist. August 1942. 47 p.

    A summary of this study is in "The Problem of Changing Food Habits,"[6] p. 74-81.

325. Kooser, J. H., and Blankenhorn, M. A. Pellagra and the public health: a dietary survey of Kentucky mountain folk in pellagrous and in nonpellagrous communities. J. Am. Med. Assoc., 116: 912-915, 1941.
326. Kostelny, A. Folk foods of a Slovakian village. J. Am. Dietetic Assoc., 11: 99-104, 1935.
327. Kruse, H. D., Palmer, C. E., Schmidt, W., and Wiehl, D. G. Medical evaluation of nutritional status. I. Methods used in a survey of high school students. Milbank Mem. Fund Quart., 18: 257-298, 1940.
328. Kuschke, B. M. Food habits in Rhode Island. R. I. Agr. Exp. Sta. Bull. 291, 1944. 25 p.
329. Kuschke, B. M., and Whittemore, M. The use of milk, fruit, and vegetables in the diet of rural Rhode Island school children. R. I. Agr. Exp. Sta. Bull. 253. 1935. 18 p.

L

330. Laird, D. A., and Breen, W. J. Sex and age alterations in taste preferences. J. Am. Dietetic Assoc., 15: 549-550, 1939.
331. Langford, W. S. The psychological aspects of feeding in early childhood. J. Am. Dietetic Assoc., 17: 208-216, 1941.
332. Langworthy, G. F. Food customs and diet in American homes. U. S. Dept. of Agr., Off. of Exp. Sta. Circ. 110, 1911.
333. Lasswell, H. D. The contribution of Freud's insight interview to the social sciences. Am. J. Soc., 45: 375-390, 1939.

334. Lautz, A., Carter, C., and Ferguson, S. Meat, sea food, eggs, and milk in the self-selected diets of college men and women. J. Home Econ., 32: 615-616, 1940.

335. Lee, W. Y., Reid, E., and Read, B. E. Industrial health in Shanghai, China. III. Shanghai factory diets compared with those of institutional workers. Chinese Med. Assoc., Spec. Rept., Series No. 7. September 1936.

336. Leichsenring, J. M., Donelson, E. G., Deinard, H. H., Pittman, M. S., Cooprider, M., and Haggart, V. Diets of 524 high school girls. J. Home Econ., 35: 583-586, 1943.

337. Leverton, R. M., and Marsh, A. G. Comparison of food intakes for weekdays and for Saturday and Sunday. J. Home Econ., 31: 111-114, 1939.

338. Levin, C. M. A study of Jewish food habits. J. Am. Dietetic Assoc., 9: 389-396, 1934.

339. Levine, R., Chein, I., and Murphy, G. The relation of the intensity of a need to the amount of perceptual distortion: a preliminary report. J. Psych., 13: 283-293, 1942.

340. Lewin, K. Dynamics of group action. Educ. Leader, 1: 195-200, 1944.

341. Lewin, K. Forces behind food habits and methods of change. *In* The problem of changing food habits, p. 35-65. *See No. 6.*

342. Lewin, K. A group test for determining the anchorage points of food habits. Comm. on Food Habits, Nat. Res. Council. June 1942. 21 p. Mimeographed.

Open-ended projective technique suitable for children from 4th grade through high school; provides information concerning likes and dislikes, usual foods eaten, and the types of people (mother, father, doctor, etc.) whom the child considers as "authorities" related to specific kinds of foods.

343. Lewin, K. The relative effectiveness of a lecture method and a method of group decision for changing food habits. Comm. on Food Habits, Nat. Res. Council. June 1942. 9 p. Mimeographed.

See also Nos. 227, 645.

Has directed a series of studies of food habits from the psychological point of view. See "The Problem of Changing Food Habits,"[6] for a summary of one of the larger studies.

344. Liddell, H. S. Conditioned reflex method and experimental neurosis. *In* Hunt, J. McV., Personality and the behavior disorders. New York, Ronald Press, 1944, p. 389-412.

345. Lindstedt, H. Food consumption habits in the Far East. Monthly Bull. Agr. Econ. Soc., 29: 399E-413E, 1938.

346. Lindstedt, H. Food consumption habits in China. Monthly Bull. Agr. Econ. Soc., 30: 363E-389E, 1939.

347. Linton, R. S. Crops, soils, and culture in America. *In* The Maya and their neighbors, p. 32-40. New York, Appleton-Century, 1940.

348. Liston, M. I. A study of quality demands in household buying of food. Vt. Agr. Exp. Sta. Bull. 415, 1937. 39 p.

349. Loomis, C. P., and Grisham, G. Spanish Americans: the New Mexican experiment in village rehabilitation. Applied Anthrop., 2: 13-37, 1943.

350. Lu, G. J., and Hinder, E. M. Nutrition and reconstruction in China. Montreal, Intern. Labour Off. In press.

351. Lu, G. D., and Needham, J. History of Chinese dietetics. Isis, 1939.

352. Luchi, A. L. Diabetes: VI. Diabetic diets and eating habits of nationalities. Penn. Med. J., 44: 41-44, 1940.

353. Lukomnik, M. An experiment to test the canalization hypothesis. Columbia Univ. Library. M.A. thesis.

354. Lund, E. M. The educational effectiveness of a school cafeteria in relation to food selection, social customs, and civic responsibilities. Ames, Iowa, Iowa State Coll., Dept. of Home Econ. Ed., 1939. 70 p. Graduate thesis.

355. Lurie, O. R. Psychological factors associated with eating difficulties. Am. J. Orthopsychiat., 11: 452-467, 1941.

M

356. McCance, R. A., Widdowson, E. M., and Verdon-Roe, C. H. A study of English diets by the individual method. III. Pregnant women at different economic levels. London, Hyg., 38: 596-622, 1938.

357. McCarrison, R. A good diet and a bad one: an experimental contrast. Ind. J. Med. Res., 14: 649-654, 1927. Supplement.

358. McCarrison, R. Problems of nutrition in India. Nutrition Abstr. and Rev., 2: 1-12, 1932.

359. McCarthy, D. Children's feeding problems in relation to the food aversions in the family. Child Developm., 6: 277-284, 1935.

360. McCay, C. M. Is longevity compatible with optimum growth? Science, 77: 410-411, 1933.

361. McCay, J. B., and Bull, H. D. Ten "good" and ten "poor" eaters. J. Pediat., 17: 230-240, 1940.

362. McCay, J. B., Waring, E. B., and Kruse, P. J. Learning by children at noon-meal in a nursery school: ten "good" eaters and ten "poor" eaters. Genet. Psychol. Monogr., 22: 491-557, 1940.

363. McClelland, B. E. The length of the sampling periods in dietary studies. Univ. of Chicago, 1931. M. A. thesis.

364. McCord, F. The effect of frustration on hoarding in rats. J. Comp. Psych., 32: 531-541, 1941.

365. McFadden, H. B. The influence of temperature and solution concentration on reaction time to taste stimuli. J. Psych., 4: 349-363, 1937.

366. McHenry, E. W. Nutrition in Toronto. Canad. Pub. Health J., 30: 4-13, 1939.

367. Mack, P. B., and Smith, J. M. Methods of conducting mass studies in human nutrition. Pa. State Coll. Bull. 43, vol. 33, 1939. 91 p.

368. Mack, P. B., Smith, J. M., Logan, C. H., and O'Brien, A. T. Mass studies in human nutrition: nutritional status of children in a college community. J. Am. Dietetic Assoc., 18: 69-78, 1942.

369. Mack, P. B., Smith, J. M., Logan, C. H., O'Brien, A. T., and Smith, F. O. Human nutrition research and improvement in mass nutritional status. Pa. State Coll. Bull. 16, vol. 36, 1942.

See also Nos. 154, 291, 679.

P. B. Mack is directing comprehensive nutrition surveys in which various diagnostic measures of nutritional status are used and cultural factors are taken into account.

370. McKay, H., and Brown, M. A. Foods used by rural families in Ohio during a three-year period. O. Agr. Exp. Sta. Bull. 492, 1931. 37 p.

371. McKay, H., and Patton, M. B. A study of the food habits and physical development of preschool children over a two-year period, with special reference to seasonal variations in growth. O. Agr. Exp. Sta. Bull. 549, 1935. 72 p.

372. McKay, H., and Patton, M. B. Food consumption of college men. O. Agr. Exp. Sta. Bull. 646, 1943. 17 p.

373. McLaughlin, E. C. G. New Zealand dietary studies. II. Dietary survey among basic wage-earners. N. Z. Med. J., 42: 155-162, 1943.

374. MacLeish, K., and Hennefrund, H. E. Anthropology and agriculture: selected references on agriculture in primitive cultures. U. S. Dept. of Agr., Bur. Agr. Econ., Agr. Econ. Bibliog. 89, 1940. 134 p.

Annotated bibliography of studies chiefly of primitive societies in all parts of the world; well-indexed.

375. McMillan, T. J., and Leverton, R. M. The self chosen diets of college girls in a cooperative dormitory. J. Home Econ., 35: 514-518, 1943.
376. Malinowski, B. Coral gardens and their magic. London, Allen & Unwin, 1935. 2 v.
377. Margolin, S. E., and Bunch, M. E. The relationship between age and the strength of the hunger motivation. Comp. Psych. Monogr., vol. 16, 1940. 34 p.
378. Maria, J. V. S. Nutrition in Chile. J. Am. Dietetic Assoc., 20: 312-314, 1944.
379. Marinho, H. Social influence in the formation of enduring preferences. J. Abn. and Soc. Psych., 37: 448-468, 1942.
380. Marshall, D. G. Changes in food habits and attitudes toward the food situation in Greendale, Wisconsin. Comm. on Food Habits, Nat. Res. Council. May 1943. 4 p. Mimeographed.
381. Marzhowska, M., and McLaughlin, L. Polish food habits. J. Am. Dietetic Assoc., 4: 142-148, 1928.
382. Masani, K. M. Dietetic deficiencies and excesses in India. Med. Bull. Bombay, 6: 431-442; 510-524; 541-553, 1938.
383. Maslow, A. H. The "emotion" of disgust in dogs. J. Comp. Psych., 14: 401-407, 1932.
384. Maslow, A. H. Comparative behavior of primates. VI. Food preferences of primates. J. Comp. Psych., 16: 187-197, 1933.
385. Maslow, A. H. Appetites and hungers in animal motivation. J. Comp. Psych., 20: 75-83, 1935.
386. Maslow, A. H. The influence of familiarization on preference. J. Exp. Psych., 21: 162-180, 1937.
386ᵃ. Maslow, A. H., and Groshong, E. Influence of differential motivation on delayed reactions in monkeys. J. Comp. Psych., 18: 75-83, 1934.
387. Masserman, J. H. Behavior and neurosis: an experimental psychoanalytic approach to psychobiological principles. Univ. of Chicago Press, 1943. 269 p.
388. Masserman, J. H. Psychodynamisms in anorexia nervosa and neurotic vomiting. Psychoanalytic Quart., vol. 10, 1941.
389. Mathews, S. J. Food habits of Georgia rural people. Ga. Agr. Exp. Sta. Bull. 159, 1929. 31 p.
390. Maurer, S. (1) The effect of early depletion of vitamin B upon performance in rats. (2) The effect of vitamin A depletion upon performance in rats. (3) The effect of a diet of pasteurized milk upon performance in rats. J. Comp. Psych., 20: 385-395, 1935.
391. Maurer, S. III. The effect of partial depletion of vitamin B (B_1) upon performance in rats. J. Comp. Psych., 20: 309-317, 1935.
392. Maurer, S., and Tsai, L. S. Vitamin B deficiency in nursing young rats and learning ability. Science, 70: 456-458, 1929.
393. Mead, M. How the Papuan plans his dinner. Natural History, 34: 377-388, 1934.
394. Mead, M. Mountain Arapesh, an importing culture. Anthrop. Papers Am. Mus. Nat. Hist., 36: 139-149, 1938.
395. Mead, M. Problem of training the volunteer in community war work. Sch. and Soc., 56: 520-522, 1942.
396. Mead, M. Reaching the last woman down the road. J. Home Econ., 34: 710-713, 1942.
397. Mead, M. Anthropological approach to dietary problems. Tr. N. Y. Acad. Sci. Series II, 5: 177-182, 1943.
398. Mead, M. Changing food habits. *In* The nutrition front, report of the N. Y. State Joint Legislative Comm. on Nutrition, p. 37-43, 1943.
399. Mead, M. Dietary patterns and food habits. J. Am. Dietetic Assoc., 19: 1-5, 1943.
400. Mead, M. Food and feeding in occupied territory. Public Opinion Quart., p. 618-628, 1943.
401. Mead, M. Food therapy and wartime food problems. J. Am. Dietetic Assoc., 19: 201-202, 1943.
402. Mead, M. Committee on Food Habits. Psych. Bull., 20: 290-293, 1943.

403. Mead, M. Factor of food habits. Ann. Am. Acad. Polit. Soc. Sci., 225: 136-141, 1943.
404. Mead, M. Problem of changing food habits. *In* The problem of changing food habits, p. 20-29. *See No. 6.*
405. Mead, M. Problem of changing food habits: with suggestions for psychoanalytic contributions. Bull. Menninger Clin., 7: 57-61, 1943.
406. Medlock, W. A study of the diet of the Southern Negro in Charlotte, N. C. Teachers College, 1927. Unpublished M. S. thesis.
407. Mellanby, E. Nerve degeneration and bone hypertrophy induced in young animals by diet. J. Physiol., 93: 42P-43P, 1938.
408. Meloan, E. L. Excessive appetite: a behavior symptom in maladjusted children. J. Pediat., 19: 632-637, 1941.
409. Métraux, R. M. Qualitative attitude analysis—a technique for the study of verbal behavior. *In* The problem of changing food habits, p. 86-94. *See No. 6.*

This method has been used in a series of studies conducted by the Committee on Food Habits, a partial list of which appears in "The Problem of Changing Food Habits"; a complete list can be obtained from the Committee office.

410. Milam, D. F. A nutrition survey of a small North Carolina community. Am. J. Pub. Health, 32: 406-412, 1942.
411. Miller, C. D. A study of the dietary and value of living of 44 Japanese families in Hawaii. Honolulu, Univ. of Hawaii, 1938. 27 p.
412. Miller, G. A., and Viek, P. An analysis of the rat's response to unfamiliar aspects of the hoarding situation. J. Comp. Psych., 37: 221-231, 1944.
413. Mitchell, H. S. Planning foods for foreign relief. J. Am. Dietetic Assoc., 19: 820-823, 1943.
414. Mitchell, H. S., and Joffe, N. F. Food patterns of some European countries: background for study programs and guidance of relief workers. J. Am. Dietetic Assoc., 20: 676-687, 1944.
415. Mitchell, H. S., and Mendel, L. B. The choice between adequate and inadequate diet as made by rats and mice. Am. J. Physiol., 58: 211-225, 1921.
416. Mitra, D. O. A study of the diet of the Bengali Hindus and their nutrition. Indian Med. Gaz., 74: 226-229, 1939.
417. Mittlemann, B., Wolff, H. G., and Scharf, M. P. Emotions and gastroduodenal function: experimental studies on patients with gastritis, duodenitis, and peptic ulcer. Psychosom. Med., 4: 5-61, 1942.
418. Moir, H. C. Some observations on the appreciation of flavour in foodstuffs. Chem. and Ind., 55: 145-148, 1936.
419. Monnier, M. Altérations du système nerveux et des muscles striés chez le rat adulte carencé en vitamine E. (Changes of the nervous system and the striate muscles in E-avitaminotic adult rats.) Z. Vitaminforsch., 11: 235-258, 1941.
420. Moore, H., and Mathias, E. The effect of vitamin A deficiency on the maze-learning ability of the white rat. J. Comp. Psych., 19: 487-496, 1935.
421. Moore, I. H. The emotional content of food habits. Proc. Archdiocesan Rural Life Conf. on Rural Prob. of N. M., July 1944.
422. Morey, N. B. A study of the food habits and health of farm families in Tompkins County, New York. Ithaca, Cornell Agr. Exp. Sta. Bull. 563, 1933. 83 p.
423. Morgan, C. T., and Morgan, J. D. Studies in hunger: I. The effects of insulin upon the rat's rate of eating. J. Genet. Psych., 56: 137-147, 1940.
424. Morgan, C. T., and Morgan, J. D. Studies in hunger. II. The relation of gastric denervation and dietary sugar to the effect of insulin upon food intake in the rat. J. Genet. Psych., 57: 153-163, 1940.
425. Morgan, C. T., Stellar, E., and Johnson, O. Food-deprivation and hoarding in rats. J. Comp. Psych., 35: 275-296, 1943.

426. Moser, A. M. Food consumption and use of time for food work among farm families in the South Carolina Piedmont. S. C. Agr. Exp. Sta. Bull. 300, 1935. 80 p.
427. Moser, A. M. Farm family diets in the lower coastal plains of South Carolina. S. C. Agr. Exp. Sta. Bull. 319, 1939. 80 p.
428. Moser, A. M. Food habits of South Carolina farm families. S. C. Agr. Exp. Sta. Bull. 343, 1942. 38 p. *See also* S. C. Exp. Sta. Rept., 1941, p. 25-30.
429. Mowrer, O. H. Animal studies in the genesis of personality. Tr. N. Y. Acad. Sci., 3: 8-11, 1940.
430. Mudge, G. G. Italian dietary adjustments. J. Home Econ., 15: 181-185, 1923.
431. Mudge, G. G. Polish dietary studies. Modern Hosp., 22: 503-504, 1924.
432. Muenzinger, K. F., and Fletcher, F. M. Motivation in learning. VI. Escape from electric shock compared with hunger-food tension in the visual discrimination habit. J. Comp. Psych., 22: 79-91, 1936.
433. Muenzinger, K. F., Poe, E., and Poe, C. F. The effect of vitamin deficiency upon the acquisition and retention of the maze habit in the white rat. II. Vitamin B_2 (G). J. Comp. Psych., 23: 59-66, 1937.
434. Munsell, H. E. Food and nutrition problems in Puerto Rico. J. Am. Dietetic Assoc., 20: 305-307, 1944.
435. Murphy, E. A study of vitamin C nutrition in a group of school children. II. Dietary evaluations. J. Nutrition, 21: 527-539, 1941.
436. Murphy, G., Murphy, L. B., and Newcomb, T. M. Experimental social psychology: an interpretation of research upon the socialization of the individual. New York, Harper, 1937. 1121 p.
437. Murrah, P. The classroom teacher and nutrition education. Understanding the Child, 11: 25-29, 1942.
438. Mursell, J. L. Contributions to the psychology of nutrition: I. Hunger and appetite. Psych. Rev., p. 317-333, 1925.
439. Muse, M., and Gillum, I. Food consumption of fifty Vermont farm households. Vt. Agr. Exp. Sta. Bull. 327, 1931. 30 p.
440. Myrdal, G., Sterner, R. M. E., and Rose, A. The American dilemma: the Negro problem and modern democracy. New York, Harper, 1944. 2 v. Append. 1, vol. 2.

N

441. Nachmansohn, D., and Steinbach, H. B. Localization of enzymes in nerves: I. Succinic dehydrogenase and vitamin B_1. J. Neurophysiol., 5: 109-120, 1942.
442. Nelson, P. M., Hoyt, E. E., McLaughlin, L., and Morgan, E. C. The food consumption habits of 145 Iowa farm families. Iowa Agr. Exp. Sta. Bull. 337, p. 329-359, 1935.
443. Nevins, W. B. Experiments in the self-feeding of dairy cows. Ill. Agr. Exp. Sta. Bull. 289, 1927.
444. New York City Comm. on Mental Hygiene of the State Charities Aid Assoc. Child Guidance Leaflets. Series on Eating. 1943. 14 leaflets.
445. New York Nutrition Assoc. Diets of Italians in New York City. 1935.
446. Nissen, H. W., and Crawford, M. P. A preliminary study of food-sharing behavior in young chimpanzees. J. Comp. Psych., 22: 383-419, 1936.
447. Nissen, H. W., and Elder, J. H. The influence of amount of incentive on delayed reaction performances of chimpanzees. J. Genet. Psych., 47: 49-72, 1935.
448. Niyogi, S. P., and Sukhatankar, D. R. A dietary survey in Bombay. Indian Med. Gaz., 74: 674-679, 1939.
449. Nizzardini, G., and Joffe, N. F. Italian food patterns and their relationship to wartime problems of food and nutrition. Comm. on Food Habits, Nat. Res. Council. August 1942. 22 p. Mimeographed.
450. Nowlis, V. Companionship preference and dominance in the social interaction of young chimpanzees. Comp. Psych. Monogr., vol. 17, no. 1, 1941. 57 p.

451. Nowlis, V. The relation of degree of hunger to competitive interaction in chimpanzees. J. Comp. Psych., 32: 91-115, 1941.

452. Nowlis, V. Sexual status and degree of hunger in chimpanzee competitive interaction. J. Comp. Psych., 34: 185-194, 1942.

453. Nutrition research in the British Colonial Empire. Imp. Bur. Anim. Nutr. (Aberdeen) Tech. Commun. 8, 1937. 46 p.

454. Nyswander, D. B. Psychological factors associated with eating. N. Y. J. Dent., 13: 10-14, 1943.

O

455. Oliver, D. A case of a change in food habits in Bougainville, British Solomon Islands. Applied Anthrop., 1: 34-36, 1942.

456. Orenstein, A. J. The dietetics of natives employed on the Witwatersrand gold mines. Africa, 9: 218-224, 1936.

457. Orr, J. B. Food, health, and income; report on a survey of adequacy of diet in relation to income. 2nd ed. London, Macmillan, 1937. 82 p.

458. Orr, J. B. Problems of African native diet. Foreword. Africa, 9: 145-146, 1936.

459. Orr, J. B., and Gilks, J. L. Studies on nutrition, the physique and health of two African tribes. London, Privy Council, Med. Res. Council. Spec. Rept. Series No. 155, H. M. Stationery Off., p. 15-82, 1931.

Detailed account of field, laboratory, and hospital work.

460. Osborne, T. B., and Mendel, L. B. The choice between adequate and inadequate diets, as made by rats. J. Biol. Chem., 35: 19-27, 1918.

461. O'Shea, H. E., Elsom, K. O'S., and Higbe, R. V. Studies of the B vitamins in the human subject: mental changes in experimental deficiency. Am. J. Med. Sci., 203: 388-397, 1942.

P

462. Parker, G. The nutrition of Virginia people as indicated by the diets of school children. Va. Agr. Exp. Sta., Rural Soc. Rept., vol. 24, 1942. 72 p.

463. Passin, H. Culture change in Southern Illinois. Rural Soc., 7: 303-317, 1942.

464. Passin, H., and Bennett, J. W. Changing agricultural magic in Southern Illinois: a systematic analysis of folk-urban transition. Social Forces, 22: 98-106, 1943.

465. Passin, H., and Bennett, J. W. Social process and dietary change. *In* The problem of changing food habits, p. 113-123. *See No. 6.*

See also No. 55.

H. Passin made an extensive anthropological study of food habits and the process of cultural change in Southern Illinois. See "The Problem of Changing Food Habits"[6] for summary of work.

466. Patton, R. A., Karn, H. W., and King, C. G. Studies on the nutritional basis of abnormal behavior in albino rats. III. The effect of different levels of vitamin B_1 intake on convulsive seizures: the effect of other vitamins in the B-complex and mineral supplements on convulsive seizures. J. Comp. Psych., 34: 85-89, 1942.

467. Pearl, R., and Fairchild, T. E. Studies on the physiology of reproduction in the domestic fowl. XIX. On the influence of free choice of food materials on winter egg production and body weight. Am. J. Hyg., 1: 253-277, 1921.

468. Pelc, H., and Podzimková-Rieglová, M. A nutrition study of a Slavic agricultural family according to a record of the food consumption for one year. Trav. Inst. Hyg. Pub. Tchécoslov., 5: 129-162, 1934.

469. Pfaffmann, C. Apparatus and technique for gustatory experimentation. J. Gen. Psych., 12: 446-447, 1935.

470. Pfaffman, M. Teaching good food habits in a clinic. Understanding the Child, 11: 17-20, 1942.

471. Philip, C. R. Nutrition in Kenya: notes on the state of nutrition of African children. E. Afr. Med. J., 20: 227-234, 1943.

472. Phillips, V., and Howell, E. L. Racial and other differences in dietary customs. J. Home Econ., 41: 396-411, 1920.

473. Phillips, W. P. Economic factors in relation to adequate diets for school children in Cardiff. Ann. Rept. Pub. Health Dept., City of Cardiff, p. 148-152, 1937.

474. Pijoan, M. Food availability and social function. New Mexico Quart. Rev., 12: 418-423, 1942.

475. Pijoan, M. Certain factors involved in the struggle against malnutrition and disease: with special reference to the Southwest of the United States and Latin America. Inter-Americana VI. Albuquerque, Univ. of New Mexico Press, 1943. 13 p.

476. Pijoan, M. The importance of a cultural approach in ameliorating nutritional defects in the Southwest. *In* The application of anthropology to problems of nutrition and population. Comm. on Food Habits, Nat. Res. Council, p. 13-22, 1944. Mimeographed.

477. Pijoan, M. Observations on the nutrition of Miskito Indians in Nicaragua. Ms. in preparation for publication.

478. Pijoan, M., and Elkin, C. A. Secondary anemia due to prolonged and exclusive milk feeding among Shoshone Indian infants. J. Nutrition, 27: 67-75, 1944.

479. Pijoan, M., Elkin, C. A., and Eslinger, C. O. Ascorbic acid deficiency among Papago Indians. J. Nutrition, 25: 491-496, 1943.

480. Pijoan, M., and Goubaud, A. Observations on food patterns and body economy in Canon de Taos. Univ. of New Mexico Press. In press.

481. Pijoan, M., and Lozner, E. L. The physiologic significance of vitamin C in man. New Eng. J. Med., 231: 14-21, 1944.

482. Pijoan, M., and Lozner, E. L. Vitamin C economy in the human subject. Johns Hopkins Hosp. Bull., 75: 303-314, 1944.

483. Pijoan, M., and Roskelley, R. W. Nutrition and certain related factors of Spanish-Americans in Northern Colorado. Denver, Rocky Mountain Council on Inter-American Affairs, 1943. 19 p.

See also Nos. 215, 282, 628.

M. Pijoan, as director of the U. S. Indian Service Nutrition Laboratory, Albuquerque, developed an approach, in collaboration with a group of anthropologists (Eggan and others), in which biological assays of nutritional status of people in the Southwest and studies of dietary practices were made; followed by an attempt to improve the diet by adding, if possible, foodstuffs familiar to the people and locally produced which also contain the necessary nutrients. Recognizes that if the energy level is extremely low from deficiencies, as it was in Indian-Spanish-American enclaves, it may be necessary to encourage the people to return to their previous diets until they acquire enough energy to make the most desirable change.

484. Pirkova-Jakobson, S., and Joffe, N. F. Some Central European food patterns and their relationship to wartime problems of food and nutrition. Czech and Slovak food patterns. Comm. on Food Habits, Nat. Res. Council. February 1943. 14 p. Mimeographed.

485. Pittman, M. S., McKay, H., Kunerth, B. L., Patton, M. B., Edelblute, N., and Cox, G. The caloric intakes of twenty-seven college women. J. Am. Dietetic Assoc., 18: 449-453, 1942.

486. Platt, B. S. Economic Advisory Council. Committee on Nutrition in the Colonial Empire, First Report. London, H. M. Stationery Off., 1939.

487. Platt, B. S., and Gin, S. Y. Chinese methods of infant feeding and nursing. Arch. Dis. Child., 13: 343-354, 1938.

488. Platt, W. Some fundamental assumptions pertaining to the judgment of food flavors. Food Res., 2: 237-249, 1937.

489. Poe, C. F., Poe, E., and Muenzinger, K. F. The effect of vitamin deficiency upon the acquisition and retention of the maze habit in the white rat. III. Vit. B_1. J. Comp. Psych., 23: 67-76, 1937.

490. Poe, E., Poe, C. F., and Muenzinger, K. F. The effect of vitamin deficiency upon the acquisition and retention of the maze habit in the white rat. I. The vitamin B-complex. J. Comp. Psych., 22: 69-77, 1936.

491. Poe, E., Poe, C. F., and Muenzinger, K. F. The effect of vitamin deficiency upon the acquisition and retention of the maze habit in the white rat. IV. Vitamins B complex; B_1, and B_2 (G). J. Comp. Psych., 27: 211-214, 1939.

492. Potgieter, M. The adequacy of diets of 38 Honolulu families on relief. Hawaii Agr. Exp. Sta. Bull. 94, 1944. 38 p.

493. Poull, L. E. The effect of improvement in nutrition on the mental capacity of young children. Child Developm., 9: 123-126, 1938.

494. Powdermaker, H. Feasts in New Ireland: the social functions of eating. Am. Anthrop., 34: 236-247, 1932.

495. Powdermaker, H. Summary of methods of a field work class cooperating with the Committee on Food Habits. *In* The problem of changing food habits, p. 95-96. *See No. 6.*

496. Preferences and practices in buying vegetables in Providence, Rhode Island. R. I. Agr. Exp. Sta. Bull. 220, 1929. 69 p.

497. Prentiss, S. W., and Jones, M. C. The observation of food habits in young children. Childhood Educ., 7: 14-17, 1930.

498. Price, M., and Gallup, G. Food habits and home production and consumption of food, a study of 256 farm families in Preble and Harrison counties, Ohio, 1941. Columbus, O. St. Univ., Coll. of Agr., Ext. Serv., 1942. 56 p.

499. Price, W. A. Calcium and phosphorus utilization in health and disease. Part II. Certified Milk, vol. 4, no. 43, 1929. 8 p.

R

500. Rahman, L., Richardson, H. B., Ripley, H. S. Anorexia nervosa with psychiatric observations. Psychosom. Med., 1: 335-365, 1939.

501. Rainey, F. Native economy and survival in Arctic Alaska. Applied Anthrop., vol. 1, no. 1, 1941.

502. Raper, A., and Tappan, P. W. Georgia sharecroppers: "Never too old to learn new tricks." Applied Anthrop., 2: 3-11, 1943.

503. Raymond, C. Food customs from abroad. Mass. Dept. Pub. Health, no. 7051, April 1939. 16 p.

504. Read, M. Native standards of living and African culture change. Africa, vol. 11, no. 3, 1938. 56 p. Supplement.

505. Ready, M. E. Factors affecting choice of food in a cafeteria. State Univ. of Iowa Library, 1943. 36 p. M. A. thesis.

506. Reh, E. Diet and nutrition of the Papago Indians. Ms. in Off. of Indian Affairs, U. S. Dept. of Interior, 1943.

507. Remington, R. E. The social origins of dietary habits. Sci. Monthly, 43: 193-204, 1936.

508. Renaud, E. B. Influence of food on Indian culture. Social Forces, 10: 97-101, 1931.

509. Renner, H. D. Origin of food habits. London, Feber & Feber, 1944. 261 p.

510. Reynolds, E. A. The relation between dietary habits and health of children in rural sections of Virginia. Va. Agr. Exp. Sta. Bull. 250, 1926. 39 p.

511. Ribble, M. A. The significance of infantile sucking for the psychic development of the individual. J. Nerv. Ment. Dis., 90: 455-463, 1939.

512. Rice, C. H. Relations of acquired food dislikes of childhood to diseases of middle life. J. Am. Med. Assoc., 75: 100-102, 1920.

513. Rice, T. B. The emotional factor in nutrition. Hygeia, 22: 100-101, 1944.

514. Richards, A. I. Hunger and work in a savage tribe; a functional study of nutrition among Southern Bantu. London, Routledge, 1932. 238 p.

515. Richards, A. I. Land, labour and diet in Northern Rhodesia, an economic study of the Bemba tribe. New York, Macmillan; London, Oxford Univ. Press, 1939.

516. Richards, A. I., and Widdowson, E. M. A dietary study in North-eastern Rhodesia. Africa, 9: 166-196, 1936.

Both descriptive and quantitative records kept of native diet. Report includes discussion of acculturation problems.

517. Richardson, F. L. W., Jr. Indian peasants: thirty years of rural reconstruction. The experiences of Spencer Hatch in Travancore. Applied Anthrop., 2: 49-56, 1943.

518. Richardson, F. L. W., Jr. African tribesmen: everybody who's hungry can belong to my church. The work of S. B. Coles. Applied Anthrop., 2: 45-49, 1943.

519. Richter, C. P. Increased salt appetite in adrenalectomized rats. Am. J. Physiol., 115: 155-161, 1936.

520. Richter, C. P. Salt taste thresholds of normal and adrenalectomized rats. Endocrin., 24: 367-371, 1939.

521. Richter, C. P. Transmission of taste sensation in animals. Tr. Am. Neurol. Assoc., 65: 49-50, 1939.
See also No. 644.

522. Richter, C. P. Behavior and endocrine regulation of the internal environment. Endocrin., 28: 193-195, 1941.

523. Richter, C. P. Decreased carbohydrate appetite of adrenalectomized rats. Proc. Soc. Exp. Biol. Med., 48: 577-579, 1941.

524. Richter, C. P. Sodium chloride and dextrose appetite of untreated and treated adrenalectomized rats. Endocrin., 29: 115-125, 1941.

525. Richter, C. P. Physiological psychology. Ann. Rev. Physiol., 4: 561-574, 1942.

526. Richter, C. P. The self-selection of diets. Essays in biology, in honor of Herbert M. Evans. Univ. of Calif. Press, 1943, p. 499-506.

527. Richter, C. P., and Barelare, B., Jr. Nutritional requirements of pregnant and lactating rats studied by the self-selection method. Endocrin., 23: 15-24, 1938.

528. Richter, C. P., and Barelare, B., Jr. Further observations on the carbohydrate, fat and protein appetite of vitamin B deficient rats. Am. J. Physiol., 126: 607-608, 1939.

529. Richter, C. P., and Campbell, K. H. Sucrose taste thresholds of rats and humans. Am. J. Physiol., 128: 291-297, 1940.

530. Richter, C. P., and Campbell, K. H. Taste thresholds and taste preferences of rats for five common sugars. J. Nutrition, 20: 31-46, 1940.

531. Richter, C. P., and Eckert, J. F. Increased calcium appetite of parathyroidectomized rats. Endocrin., 21: 50-54, 1937.

532. Richter, C. P., and Eckert, J. F. Mineral appetite of parathyroidectomized rats. Am. J. Med. Sci., 198: 9-16, 1939.

533. Richter, C. P., and Hawkes, C. D. The dependence of the carbohydrate, fat and protein appetite of rats on the various components of the vitamin B complex. Am. J. Physiol., 131: 639-649, 1941.

534. Richter, C. P., Holt, L. E., Jr., and Barelare, B., Jr. Vitamin B_1 craving in rats. Science, 86: 354-355, 1937.

535. Richter, C. P., Holt, L. E., Jr., and Barelare, B., Jr. Nutritional requirements for normal growth and reproduction in rats studied by the self-selection method. Am. J. Physiol., 122: 734-744, 1938.

536. Richter, C. P., Holt, L. E., Jr., Barelare, B., Jr., and Hawkes, C. D. Changes in fat, carbohydrate and protein appetite in vitamin B deficiency. Am. J. Physiol., 124: 596-602, 1938.

537. Richter, C. P., and MacLean, A. Salt taste threshold of humans. Am. J. Physiol., 126: 1-6, 1939.

538. Richter, C. P., and Schmidt, C. H., Jr. Increased fat and decreased carbohydrate appetite of pancreatectomized rats. Endocrin., 28: 179-192, 1941.

> C. P. Richter, working in the Psychobiological Laboratory of Johns Hopkins Hospital, has developed an experimental technique for study of rats' self-selection of diets and influence of various physiological states on the selection.

539. Ridenour, N., and Williams, E. Balanced diets and balanced personalities. Understanding the Child, 11: 11-16, 1942.
540. Roberts, L. J. Children of pre-school age in Gary, Indiana. *In* Diet of children. Part II, p. 53-128. U. S. Dept. of Labor, Children's Bur. Pub. 122, 1922.
541. Roberts, L. J. The nutrition and care of children in a mountain county of Kentucky. U. S. Dept. of Labor, Children's Bur. Pub. 110, 1922. 41 p.
542. Roberts, L. J. The psychologists study eating habits. Child Study, 7: 35-38, 1929.
543. Roberts, L. J. Nutrition in Puerto Rico. J. Am. Dietetic Assoc., 21: 298-304, 1944.
544. Roberts, W. O. Dakota Indians: successful agriculture within the reservation framework. Applied Anthrop., 2: 37-44, 1943.
545. Robinson, W. D., Payne, G. C., and Calvo, J. A study of the nutritional status of a population group in Mexico City. J. Am. Dietetic Assoc., 20: 289-297, 1944.
546. Rogerson, B. C. F., and Rogerson, C. H. Feeding in infancy and subsequent psychological difficulties. J. Ment. Sci., 85: 1163-1182, 1939.
547. Rose, J. A. Eating inhibitions in children in relation to anorexia nervosa. Psychosom. Med., 5: 117-124, 1943.
548. Rose, M. S. Racial food habits in relation to health. Sci. Monthly, 44: 257-267, 1937.
549. Roulx, L. L'alimentation en Haiti. Bulletin du Service National d'Hygiene et d'Assistance Publique et Sanitaire, no. 14. September 1937.
550. Ruch, F. L. Effect of inanition upon maze learning in the white rat. J. Comp. Psych., 14: 321-329, 1932.

S

551. Sadow, S. E. Jewish ceremonials and food customs. J. Am. Dietetic Assoc., 4: 91-98, 1928.
552. Sanford, R. N. The effects of abstinence from food upon imaginal processes. J. Psych., 2: 129-136, 1936.
553. Sanford, R. N. The effects of abstinence from food upon imaginal processes: a further experiment. J. Psych., 3: 145-159, 1937.
554. Santos, F. O., and Demeterio, J. K. Studies on the food of labourer's families in Macrohon, Leyte. Philip. Agriculturist, 28: 15-24, 1939.
555. Saunders, J. L., and Taylor, R. M. S. The dental condition and diet of the Maoris of Maungapohatu Village. New Zealand Dept. of Health, Ann. Rept. of Director General, Append. C, 1936-1937, p. 64 and ff.
556. Saunders, L. A guide to materials bearing on cultural relations in New Mexico. School of Inter-American Affairs. Univ. of New Mexico Press, 1944.
557. Scantlebury, R. E., and Patterson, T. L. The effect of certain psychic phenomena on the various phases of gastric hunger contractions. Am. J. Physiol., 123: 179-180, 1938.
558. Scheltema, A. M. P. A. The food consumption of the native inhabitants of Java and Madura. Batavia, Ruygrok & Co., 1936. 143 p.
559. Schmideberg, M. Intellectual inhibition and disturbances in eating. Internat. J. Psycho-Analysis, 19: 17-22, 1938.
560. Seay, M. F., and Meece, L. E. The Sloan experiment in Kentucky. Bull. Bur. School Serv., vol. 16, no. 4, 1944. 131 p.
561. Self-selection of diets. Nutrition Rev., 2: 199-203, 1944.
562. Selling, L. Malnutrition and the problem child. Nervous Child, 3: 187-194, 1944.
563. Shock, N. W. Physiological factors in behavior. *In* Hunt, J. McV., Personality and the behavior disorders. New York, Ronald Press, 1944, p. 582-618.

564. Shourie, K. L. A survey of diet and nutrition in Najafgarh, Delhi Province. Indian J. Med. Res., 26: 907-920, 1939.
565. Siegal, E. H., Waugh, L. M., and Karshan, M. Dietary and metabolic studies of children with and without dental caries, including studies of metabolic balances of calcium, phosphorus, and nitrogen. Am. J. Dis. Child., 59: 19-38, 1940.
566. Siegel, M., and King, M. Food habits of Spanish-Americans at Cundiyo, New Mexico. Comm. on Food Habits, Nat. Res. Council, 1943. Ms., 200 p.
567. Simmons, R. The relative effectiveness of certain incentives in animal learning. Comp. Psych. Monogr., vol. 2, no. 7, 1924. 79 p.
568. Skinner, A. Material culture of the Menomine. IV. Food and its preparation. Ind. Notes and Monogr., 20: 142-208, 1921. New York Mus. of the Am. Ind., Heye Found.
569. Skinner, B. F. The behavior of organisms: an experimental analysis. New York, Appleton-Century, 1938. 457 p.
570. Skinner, B. F. A method of maintaining an arbitrary degree of hunger. J. Comp. Psych., 30: 139-145, 1940.
571. Sladden, D. E. Transference of induced food-habit from parent to offspring. Part I. Proc. Roy. Soc. London, 114B: 441-449, 1933.
572. Sladden, D. E., and Hewer, H. R. Transference of induced food-habit from parent to offspring. III. Proc. Roy. Soc. London, Series B, 126: 30-44, 1938.
573. Slonaker, J. R. The effect of a strictly vegetable diet on the spontaneous activity, the rate of growth, and the longevity of the albino rat. Leland Stanford Jr. Univ. Pub., 1912.
574. Smith, A. J., and Field, A. A study of the effect of nutrition on mental growth. J. Home Econ., 18: 686-690, 1926.
575. Smith, W. H. and E. M. Native diet in Zanzibar. E. Africa Med. J., 12: 246-251, 1935.
576. Spezzafumo, O. Enguête sur l'alimentation dans la population italienne ouvrière de Tunis. Arch. Inst. Pasteur Tunis, 29: 113-125, 1940.
577. Spock, B. The occasions when feeding problems begin. Nervous Child, 3: 162-164, 1944.
578. Stamm, E. K., and Wiehl, D. G. Medical evaluation of nutritional status. VIII. The school lunch as a method for improving diets of high school students. Milbank Mem. Fund Quart., 20: 83-96, 1942.
579. Standards for interpretation of dietary surveys. Nutrition Rev., 2: 264-266, 1944.
580. Stefansson, V. Food tastes and food prejudices of men and dogs. Sci. Monthly, 11: 540-543, 1920.
581. Stefansson, V. Adventures in diet. Harpers, 171: 668-675, 1935; 172: 46-54, 178-189, 1936.
582. Stefansson, V. Food of ancient and modern stone age man. J. Am. Dietetic Assoc., 13: 102-119, 1937.
583. Stefansson, V. Pemmican. Mil. Surgeon, 95: 89-98, 1944.
584. Steggerda, M., and Eckardt, R. B. Navajo foods and their preparation. J. Am. Dietetic Assoc., 17: 217-221, 1941.
585. Stellar, E. The effect of epinephrine, insulin, and glucose upon hoarding in rats. J. Comp. Psych., 36: 21-32, 1943.
586. Stellar, E., and Morgan, C. T. The roles of experience and deprivation in the onset of hoarding behavior in the rat. J. Comp. Psych., 36: 47-55, 1943.
587. Stene, J. A., and Roberts, L. J. A nutrition study on an Indian reservation. J. Am. Dietetic Assoc., 3: 215-222, 1928.
588. Sterba, E. An important factor in eating disturbances of childhood. Psychoanalytic Quart., 10: 365-372, 1941.
589. Stern, F. The nutritionist looks at mental hygiene. Ment. Hyg., 14: 54-66, 1930.
590. Stevens, H. Avitaminosis B (B_1), maze performance, and certain aspects of brain chemistry. J. Comp. Psych., 24: 441-458, 1937.
591. Stevenson, H. N. C. Feasting and meat division among the Zahau Chins of Burma: a preliminary analysis. London, J. Roy. Anthrop. Inst., 67: 15-32, 1937.

592. Stiebeling, H. K., Monroe, D., Coons, C. M., Phipard, E. F., and Clark, F. Family food consumption and dietary levels: five regions. Consumer Purchases Study, Farm Series, U. S. Dept. of Agr. Misc. Pub. 405, 1941. 393 p.

593. Stiebeling, H. K., Monroe, D., Phipard, E. F., Adelson, S., and Clark, F. Family food consumption and dietary levels: five regions. Consumer Purchases Study, Urban and Village Series, U. S. Dept. of Agr. Misc. Pub. 452, 1941. 268 p.

594. Stiebeling, H. K., and Munsell, H. E. Food supply and pellagra incidence in 73 South Carolina farm families. U. S. Dept. of Agr. Tech. Bull. 333, 1932. 36 p.

595. Stiebeling, H. K., and Phipard, E. F. Diets of families of employed wage earners and clerical workers in cities. U. S. Dept. of Agr. Cir. 507, 1939. 141 p.

596. Stone, C. P. A simple method for developing olfactory discrimination habits in rats. J. Genet. Psych., 58: 419-421, 1941.

597. Sullivan, R. J. The Ten'a food quest. Washington, D. C., Catholic Univ. of Am. Anthrop. Series 11, 1942. 142 p.

598. Sweeny, M. Changing food habits. J. Home Econ., 34: 457-462, 1942.

599. Sweetman, M. D. The scientific study of the palatability of food. J. Home Econ., 23: 161-172, 1931.

T

600. Thurston, F. M. A preliminary study of the factors affecting the time taken by nursery school children to eat their food. J. Genet. Psych., 36: 303-318, 1929.

601. Titiev, M. Hopi method of baking sweet corn. Papers Mich. Acad. Sci., Arts and Letters, 23: 87-94, 1937.

602. Tomhave, A. E., and Mumford, C. W. Self-selection of feeds by hens. Del. Agr. Exp. Sta. Bull. 174, 1931.

603. Tsang, Yu-Chuan. Hunger motivation in gastrectomized rats. J. Comp. Psych., 26: 1-17, 1938.

604. Turlay, M. E. A survey of the diets of West Coast industrial workers. J. Am. Dietetic Assoc., 19: 567-569, 1943.

605. Turner, C. E. Significant findings of the Massachusetts high school study and their implications for health education programs. J. School Health, 13: 9-17, 1943.

606. Tussing, L. A study of sex differences in food likes and dislikes. Proc. Ind. Acad. Sci., 48: 198-199, 1939.

U

607. United States Department of Agriculture. Family food consumption in the United States, Spring, 1942. Misc. Pub. No. 550, 1944. 157 p.

608. United States Department of Agriculture. National wartime food guide. NFC 4 Revised, July 1944. 8 p.

609. United States Department of Agriculture, War Food Admin. A brief review of food and nutrition in five countries. 1943. 28 p.

610. United States Department of Agriculture, War Food Admin. Democracy means all of us: how communities can organize to study and meet community needs with special suggestions for developing nutrition programs in wartime. August 1943. 30 p.

611. United States Department of Agriculture, War Food Admin. Food consumption levels in the United States, Canada, and the United Kingdom. 1944. 21 p.

V

612. Vance, T. F. Food selections of nursery school children. Child Developm., 3: 169-175, 1932.

613. Vance, T. F., and Temple, V. M. The food preferences of preschool children: a comparison of rural children with children of the Iowa State College nursery school. Child Developm., 4: 222-228, 1933.

614. Vaughan, W. T. Why we eat what we eat. Sci. Monthly, 50: 148-154, 1940.

615. Viek, P., and Miller, G. A. The cage as a factor in hoarding. J. Comp. Psych., 37: 203-210, 1944.
616. Vitamins and fatigue. Nutrition Rev., 1: 227-229, 1943.
617. Vitamins and physical fitness. Nutrition Rev., 2: 115-117, 1944.
618. Vitamin B-complex and hard work. Nutrition Rev., 2: 334-336, 1944.

W

619. Wald, G., and Steven, D. An experiment in human vitamin A deficiency. Am. J. Physiol., 126: 648, 1939.
620. Wallen, R. Sex differences in food aversions. J. Appl. Psych., 27: 288-298, 1943.
621. Waller, J. V., Kaufman, R. M., and Deutsch, F. Anorexia nervosa: a psychosomatic entity. Psychosom. Med., 2: 3-16, 1940.
622. Walter, D. H. Sources of food and some factors affecting consumption in the borough of State College, Pennsylvania. Pa. Agr. Exp. Sta. Tech. Paper 601, 1933. 34 p.
623. Warden, C. J., and Jackson, T. A. A preliminary study of the hunger drive in the Rhesus monkey. J. Genet. Psych., 46: 126-218, 1935.
624. Warkentin, J., Warkentin, L., and Ivy, A. C. The effect of experimental thyroid abnormalities on appetite. Am. J. Physiol., 139: 139-146, 1943.
625. Warner, L. H. A study of hunger in the white rat by means of the obstruction method. J. Comp. Psych., 8: 273-299, 1928.
626. Watson, J. B. A study of nutritional problems among the Hopi. Ms. in Off. of Indian Affairs, U. S. Dept. of Interior.
627. Watson, J. B. How the Hopi classify their foods. Plateau, 15: 49-52, 1943.
628. Watson, J. B., and Pijoan, M. Hopi foodways. Ms. in Off. of Indian Affairs, U. S. Dept. of Interior. 1943. 204 p.
629. Waugh, F. W. Iroquois foods and food preparation. Geol. Survey of Can., Mem. 86, 1916.
630. Wentworth, K. L. The effect of a native Mexican diet on learning and reasoning in white rats. J. Comp. Psych., 22: 255-267, 1936.
631. Whitacre, J. The diet of Texas school children. Texas Agr. Exp. Sta. Bull. 489, 1931. 44 p.
632. Whitacre, J. The food supply of Texas rural families. Texas Agr. Exp. Sta. Bull. 642, 1943. 40 p. Also see Bull. 643, 1943, by the same author.
633. Wiehl, D. G. Diets of low-income families in New York City. Milbank Mem. Fund Quart., 11: 308-324, 1933.
634. Wiehl, D. G. Diets of low-income families in Cleveland, Detroit, and Syracuse. Milbank Mem. Fund Quart., 12: 35-46, 1934.
635. Wiehl, D. G. Diets of urban families with low incomes. Milbank Mem. Fund Quart., 12: 343-369, 1934.
636. Wiehl, D. G. Diets of low income families surveyed in 1933. U. S. Pub. Health Repts., 51: 77-97, 1936.
637. Wiehl, D. G. Diets of a group of aircraft workers in Southern California. Milbank Mem. Fund Quart., 20: 329-366, 1942.
638. Wiehl, D. G. Medical evaluation of nutritional status. VII. Diets of high school students of low-income families in New York City. Milbank Mem. Fund Quart., 20: 61-82, 1942.
639. Wiehl, D. G. Medical evaluation of nutritional status. XV. Caloric intake of high school students in New York City. Milbank Mem. Fund Quart., 22: 5-40, 1944.
640. Wiehl, D. G., and Palmer, C. E. Summer diets of the poor in Washington, D. C. Milbank Mem. Fund Quart., 17: 5-28, 1939.
641. Wilder, C. E. Selection of rachitic and anti-rachitic diets in the rat. J. Comp. Psych., 24: 547-577, 1937.
642. Wilder, J. Malnutrition and mental deficiency. Nervous Child, 3: 174-186, 1944.
643. Wilder, R. M. Role of nutritional deficiency in nervous and mental disease; symptoms and signs of thiamine deficiency. Assoc. Res. Nerv. Ment. Dis., Proc., 22: 101-112, 1943.

644. Wilkins, L., and Richter, C. P. A great craving for salt by a child with cortico-adrenal insufficiency. J. Am. Med. Assoc., 114: 866-868, 1940.

645. Willerman, B. Group decision and request as means of changing food habits. Comm. on Food Habits, Nat. Res. Council. April 1943. 11 p. Mimeographed.

646. Williams, F. M., Stiebeling, H. K., Swisher, I. G., and Weiss, G. S. Family living in Knott County, Kentucky. U. S. Dept. of Agr. Tech. Bull. 576, 1937. 69 p.

647. Williams, F. M., and Zimmerman, C. C. Studies of family living in the United States and other countries: an analysis of material and methods. U. S. Dept. of Agr. Misc. Pub. No. 223, 1935. 617 p.

Is an annotated bibliography with key to material and method, indicating studies which include data on food consumption and nutritive content of diet; complete for entire world.

648. Williams, R. D., Mason, H. L., Cusick, P. L., and Wilder, R. M. Observations on induced riboflavin deficiency and the riboflavin requirement of man. J. Nutrition, 25: 361-377, 1943.

649. Wilson, C. The diets of Hartford school children. Hartford, Bd. of Educ., 1941. Mimeographed.

650. Wilson, D. C., and Widdowson, E. M. A comparative nutritional survey of various Indian communities. Ind. Med. Res. Mem. No. 34, March 1942. 119 p.

651. Winters, J. C. A report on the health and nutrition of Mexicans living in Texas. Texas Univ. Bur. Res. in the Soc. Sci., Study No. 2, Texas Univ. Bull. 3127, 1931. 99 p.

652. Winters, J. C., and Leslie, R. E. A study of the diet of 20 women in a moderate income group. J. Nutrition, 27: 185-192, 1944.

653. Wolbach, S. B., and Bessey, O. A. Vitamin A deficiency and the central nervous system. Am. J. Path., 17: 586, 1941.

654. Wolf, A. W. M. Understand emotions to improve nutrition. Understanding the Child, 11: 21-24, 1942.

655. Wolfe, J. B. An exploratory study of food-storing in rats. J. Comp. Psych., 28: 97-108, 1939.

656. Wolfle, D. L., and Wolfle, H. M. The development of cooperative behavior in monkeys and young children. J. Genet. Psych., 55: 137-175, 1939.

657. Wood, L. Food likes and dislikes of forty-eight children as studied in a nursery school for fifty-four weeks. *In* The pre-school child: his development and his guidance: a conference held at Mills College, Calif., April 6, 7, and 8, 1928. Oakland, Mills Coll. Bull. Series 18, no. 6, 1928. 172 p.

658. Woodbury, R. M. Food consumption and dietary surveys in the Americas. Montreal, Internat. Lab. Off., 1942. 64 p.

659. Woods, C. D., and Mansfield, E. R. Studies of the food of Maine lumbermen. U. S. Dept. of Agr., Off. of Exp. Sta. Bull. 149, 1904. 60 p.

660. Woodward, P. Attitudes toward the use of soybeans as food. Comm. on Food Habits, Nat. Res. Council. October 1943. 11 p. Mimeographed.
See also No. 309.

Has written other reports, a partial list of which appears in "The Problem of Changing Food Habits"; a complete list can be obtained from the Committee office.

661. Woodward, P. The relative effectiveness of different combinations of appeals in presenting a new food—soya. To be published.

662. Worthington, E. B. On the food and nutrition of African natives. Africa, 9: 150-165, 1936.

663. Wright, M. D. The Oslo meal: its acceptability among industrial workers. J. Roy. Inst. Pub. Health & Hyg., 3: 3-8, 1940.

Y

664. Yamashita, T. Studies on fundamental habits in early childhood. I and II. Kyoiku, 4: 648-672, 1936; 5: 93-110, 1937.

665. Youmans, J. B., Patton, E. W., and Kern, R. Survey of the nutrition of populations. Description of population, general methods and procedures, and findings in respect to energy principle (calories) in rural population in middle Tennessee. Am. J. Pub. Health, 33: 58-72, 1943.

666. Youmans, J. B., Patton, E. W., Sutton, W. R., Kern, R., and Steinkamp, R. Surveys of the nutrition of populations. 2. The protein nutrition of a rural population in middle Tennessee. Am. J. Pub. Health, 33: 955-964, 1943.

667. Young, A. A method for the evaluation of a community nutrition program. J. Am. Dietetic Assoc., 19: 420-427, 1943.

668. Young, E. G. A dietary survey in Halifax. Canad. Pub. Health J., 32: 236-240, 1941.

669. Young, P. T. Studies in affective psychology. VI. Preferential discrimination of the white rat for different kinds of growth. Am. J. Psych., 40: 372-394, 1928.

670. Young, P. T. Relative food preferences of the white rat. J. Comp. Psych., 14: 297-319, 1932.

671. Young, P. T. Relative food preferences of the white rat. II. J. Comp. Psych., 15: 149-165, 1933.

672. Young, P. T. Food preferences and the regulation of eating. J. Comp. Psych., 15: 167-176, 1933.

673. Young, P. T. Preferences and demands of the white rat for food. J. Comp. Psych., 26: 545-589, 1938.

674. Young, P. T. Reversal of food preferences of the white rat through controlled prefeeding. J. Gen. Psych., 22: 33-66, 1940.

675. Young, P. T. The experimental analysis of appetite. Psych. Bull., 38: 129-164, 1941.

676. Young, P. T. Emotion in man and animal. New York, John Wiley & Sons, Inc., 1943. p. 125-155.

677. Young, P. T. Food preferences, food habits, and appetites of the rat. *In* Research on appetite levels. Comm. on Food Habits, Nat. Res. Council. February 1944, p. 47-54. Mimeographed.

678. Young, P. T., and Wittenborn, J. R. Food preferences of rachitic and normal rats. J. Comp. Psych., 30: 261-277, 1940.

P. T. Young, as an experimental psychologist, has developed and used techniques for studying appetite experimentally, including animals' preferences for different foods, and the influence of numerous variables such as relative positions of foods, physiological need for a food, use or non-use of head receptors in the choice situation, on the choice of food.

Z

679. Zayaz, S. L., Mack, P. B., Sprague, P. K., and Bauman, A. W. Nutritional status of school children in a small industrial city. Child Developm., 11: 1-25, 1940.

680. Ziegler, L. H., and Knudson, A. Quantitative analysis of activity after recovery from rickets: an experimental study. J. Comp. Psych., 24: 119-126, 1937.

681. Zimmerman, H. M. The pathology of the nervous system in vitamin deficiencies. Yale J. Biol. & Med., 12: 23-28, 1939.

682. Zimmerman, H. M., and Cowgill, G. R. Lesions of the nervous system in vitamin deficiency. IV. The effect of carotene in the treatment of the nervous disorder in rats fed on a diet low in vitamin A. J. Nutrition, 11: 411-423, 1936.

PARTIAL INDEX TO ALPHABETICAL BIBLIOGRAPHIES

1. Some Regional Studies *

- AMERICA 658
  - *Canada* 213, 214, 258, 298, 366, 611, 668
  - *Central America* 51, 98, 253, 477
  - *The Indians of North America*
    - Canada 70, 293
    - Eskimos 501, 565, 583
    - United States 36, 103, 106, 107, 108, 155, 160, 282, 478, 479, 506, 508, 544, 568, 584, 587, 597, 601, 626-9
  - *Mexico* 50, 246, 347, 545, 609
  - *South America*
    - Brazil 109
    - Colombia 51
    - Chile 378
  - *West Indies*
    - Cuba 105
    - Haiti 549
    - Puerto Rico 176, 434, 543
- EUROPE 14, 414
  - *Czechoslovakia* 326, 414, 468, 484
  - *Germany* 175
  - *Great Britain* 85, 110-3, 116, 123-7, 206, 219, 356, 453, 457, 486, 611, 663
  - *Hungary* 264, 306, 414
  - *Italy* 449
  - *Netherlands* 414, 609
  - *Poland* 54, 381, 414
  - *Scandinavia* 69, 414
- ASIA 11
  - *China* 11, 117-8, 143, 335, 345, 346, 350-1, 487, 609
  - *India and Ceylon* 11, 169, 247, 255, 287, 345, 357-8, 382, 416, 448, 517, 564, 609, 650
  - *Indo-China* 11
    - Burma 11, 345, 591
    - Siam 11
  - *Indonesia* 11, 190, 230, 345, 558
  - *Japan* 11, 345, 664
  - *Korea* 73, 345
  - *Syria* 189
- AFRICA
  - *Egypt* 609
  - *Primitive Societies* 34, 158, 229, 233, 284, 374, 458-9, 471, 504, 514-6, 518, 575, 662
  - *Tunis* 576
  - *Union of South Africa* 132, 456

---

* No attempt has been made for geographic inclusiveness but references selected for methodological reasons are here arranged geographically for the convenience of the research worker.

- AUSTRALIA AND NEW ZEALAND
  - *New Zealand* 261, 373
    - Maoris 555
- PACIFIC ISLANDS 11
  - *Hawaiian Islands* 48, 223, 410, 492
  - *Philippine Islands* 11, 267, 554
  - *Primitive Societies* 97, 207, 374, 376, 393, 455, 494

2. Studies Within the United States

7, 25, 30, 159, 269, 332, 592-5, 607, 611, 620, 635-6, 647

a. REGIONAL

- NORTHEASTERN STATES
  - *Middle Atlantic*
    - District of Columbia 640
    - Maryland 99, 134, 204
    - New York 82, 89, 100, 177, 203, 252, 283, 324, 327, 361-2, 422, 445, 493, 578, 600, 633-4, 638-9
    - Pennsylvania 67, 154, 291, 367-9, 622, 679
  - *New England* 315
    - Connecticut 122, 268, 319, 649
    - Maine 129-31, 194, 198-9, 202, 435, 659
    - Massachusetts 170, 216
    - Rhode Island 328-9, 496
    - Vermont 84, 283, 348, 439
- SOUTH 316
  - *South Atlantic*
    - Georgia 166, 359, 389, 502
    - North Carolina 166, 406, 410
    - South Carolina 166, 236-7, 426-8, 594
    - Virginia 510
  - *South Central*
    - Alabama 35, 66, 574
    - Kentucky 83, 325, 541, 560, 646
    - Mississippi 180-7
    - Tennessee 72, 334, 665-6
- NORTH CENTRAL 191
  - *Northwest*
    - Iowa 227, 341-3, 442, 505, 612-3, 645
    - Kansas 336, 485
    - Minnesota 212, 336, 643, 648
    - Nebraska 337, 375
  - *Old Northwest*
    - Illinois 55-7, 68, 271, 463-5
    - Indiana 301, 540, 606
    - Michigan 101, 249, 277
    - Ohio 269, 370-2, 485, 498, 634
    - Wisconsin 156-7, 288
- OLD SOUTHWEST
    - Louisiana 96, 133, 263
    - Oklahoma 260
    - Texas 205, 244, 631-2, 651-2

FAR WEST
  Northwest
    Washington 218
  Southwest
    California 45, 74, 75, 497, 604, 637, 657
    Colorado 483
    New Mexico 106, 251, 349, 474-6, 480, 556, 566
    Utah 86-8

b. ETHNIC GROUPS

31, 304, 352, 472, 503

Chinese-Americans 281, 302
Czech and Slovak-Americans 484
Hungarian-Americans 306
Italian-Americans 31, 167, 319, 430, 445, 449
Jewish-Americans 104, 338, 551
Mexican-Americans 31, 651
Negro-Americans 31, 35, 71, 310, 406
Polish-Americans 31, 54, 431

3. Theoretical Articles

33, 40, 57, 94, 126, 153, 161, 174, 192, 198, 199, 207, 215, 220, 229, 233, 240, 246, 259, 280, 294, 312, 313, 333, 341, 347, 376, 385, 397-405, 421, 464, 474, 504, 507, 509, 513-6, 547, 548, 589, 598, 614, 662, 675

4. Psychosomatic Studies

27-9, 90-3, 95, 135, 153, 179, 208-10, 220, 238, 242, 286, 304, 355, 387, 408, 454, 500, 512, 513, 547, 559, 589, 621, 656

5. Studies of Children

12, 37, 58, 65, 67, 68, 89, 90-3, 101, 120, 178, 207, 212, 216, 240, 243, 254, 286, 331, 355, 359, 361-2, 408, 437, 444, 454, 470, 487, 497, 512, 539, 542, 546, 547, 562, 577, 588, 600, 612, 613, 642, 654, 657, 664

WITH SPECIAL REFERENCE TO CHILDREN'S DIETS

129, 133, 170, 244, 277, 329, 371, 435, 462, 510, 540

6. Methods *

a. SOME OBSERVATIONAL METHODS

Analysis of verbatim material, such as interviews and essays 123-7, 309, 409, 660
Attitude tests 83
Check-lists 202, 269, 283, 606, 620
Diet histories 271, 372
Diet records 4, 50, 82, 180, 236, 428
Evaluations of some observational techniques 295, 579
Grocery sales slips 282, 367, 442

---

* Only some studies which are representative of the various types of methods are listed here.

Interviews 92-3, 179, 184, 237, 341, 359, 360
Observations of choice of food 288, 612, 613, 661
Observations of reactions to food 212, 250, 308, 413
Projective methods 339, 342, 553
Quantitative measurements of food 25, 410, 422, 516
Questionnaires 96, 237, 328, 496
Rating scales 68, 101, 216, 361-2, 497

b. SOME EXPERIMENTAL METHODS

Influence of social and emotional conditions on animals' behavior toward food
  Emotional 78, 248, 344, 387, 417, 557
  Social 44, 265, 273, 274, 429, 446, 450
Methods of changing animals' food preferences 278, 674, 677
Methods of changing food choices of people 47, 211, 250, 292, 340, 341, 343, 354, 379, 505, 645
Methods of studying deficient animals' ability to select nutritionally desirable food mixture from several 276, 311, 641, 678
Methods of studying degree of hunger 77, 79-80, 228, 285, 339, 377, 552, 569-70, 623, 625
Methods of testing animals' food preferences 200, 239, 596, 670, 671, 673
Self-selection of diets 128, 171, 195, 535, 561
Studies of effect of deprivation on animals' behavior toward food 226, 296, 364, 412, 425, 586, 615
Studies of effect of nutritional status on learning ability and performance
  Learning of animals 59-61, 62, 241, 303, 390-2, 489-91
  Learning of children 243, 258, 275, 574
  Performance 188, 318, 616-8
Studies of food and taste preferences of human beings 20, 314, 330, 418
Studies of influence of previous experience on animals' selection of diet 276, 311, 677, 678

7. BIBLIOGRAPHIES

31, 175, 242, 374, 556, 647

INDEX

Action, basis for, 26
Aged, 16, 23, 39, 81, 83
Agriculture, 31
Agronomist, 16, 17
Alcohol, 63, 68, 71
  alcoholism, 45
Allee, 76, 77
Allergies, 23, 45
Americans, 23, 34, 35, 48
Animals
  ability to select, 61, 62, 63, 65-69
  abnormal behavior, 79, 80
  adrenalectomy, 62
  control, 61, 70, 72, 73, 79, 91
  education of, 67
  experiments, 61, 65-67, 70, 72-79
  feeding, 91
  how change, 84, 90
  internal environment, 62
  maze learning, 91, 92
  nutritional instinct, 62
  parathyroidectomy, 62
  social behavior, 76-79
  social organization, 77, 78
Anthropology, 14, 18, 23, 27, 48, 57
Appetites, 42, 46, 61, 63, 66, 69, 70, 71, 83, 90
Arthur Performance Scale, 92
Attitudes
  adult, 42
  deviant, 44
  dynamics of, 48
  early, 56, 84
  general, 13, 40
  hunger, 82
  interviews used, 57
  local, 50
  parental, 43
  population, 49
  public, 17
  regional, 41
  verbatim, 88
  waste, 36, 37
  See also Cultural
Autistic process, 82
Availability, 16, 64, 85
Balken, 92
Bavelas, 89
Bayer, 69, 71, 76
Bayroff, 77
Bennett, 48, 57
Bernard, Claude, 62
Biel, 91
Biochemistry, 14, 15, 16, 17, 36, 91
Bodily practices, 26, 56, 79
Bousfield, 79, 81
Breen, 83
Bruch, Hilde, 27, 57
Bunch, 80
Bureau of Human Nutrition and Home Economics, 35
Cafeteria studies, 16, 86, 87, 88, 89
California, 41
Canada, 39
Canalization, 66, 85
Cats, 75
Cedar Rapids study, 41, 48, 49
Chaney, 83
Chein, 82
Chemistry, 14, 63, 91
Chicks, 36, 61, 65, 68, 69, 81
Children
  care of, 34
  food choices, 15, 16, 38, 41, 64, 86
  free choices, 63
  obese, 27
  school, 19, 32, 41, 49, 87
  statements, 38, 56
  training, 13, 27, 40, 43, 44, 45
  See also Nursery schools, Infants
Chimpanzees, 77, 78
Chinese, 27
Clark, 62
Classification of, 41
Class typing, 34, 38
Clausen, 62
Committee on Food Habits, 3, 4, 57
Community study, 89
Competition, 77, 78, 79
Conditioning, 79, 80, 81, 91
Consumption, post war, 36, 43
  studies, 34, 35, 36, 39, 55, 58
"Context for the Collection of Data," 27
Cooking, 33, 34, 40, 43
Cows, 61
Crawford, 77
Cultural
  classification, 41
  consistencies of, 58
  context, 49
  data, 19, 44
  food use, 37
  frame, 48
  limited concept, 42

  method, 27
  pattern, 17
  personal, 40
  pressures, 13
  principles, 25
  restaurants, 50
  varieties of, 24
Cussler, Margaret T., 47, 56
Data, 13, 15, 18, 19, 26, 93
  basic, 23, 24
  concrete, 27, 28
  core of, 51
  identification, 26
Davis, 63, 83
Deficiency, 75, 76, 90, 92
  See also Vitamins
Definition of study, 13
De Give, Mary L., 47, 56
De Haan, Bierens, 70
Democracy, 25
Deprivation, 70, 73-81, 91
  relative, 72
Deutsch, 45
Diet
  army, 17
  balanced, 62, 63
  changes in, 14, 34, 48
  choices, 64
  evaluation of, 31
  history, 55
  McCollum, 62, 63
  Mexican, 91
  predetermined, 61
  Sikhs, 91
  standard, 38, 61
  uncertainties of, 31
Dietary laws, 39, 42
Diseases, 16, 23, 45, 57, 63, 64
  Addisons', 63
  tuberculosis, 89
Dish washing, 37
Disposal of waste, 36, 37
Distribution of food, 13, 26, 31, 33, 34, 37, 39
Division of labor, 37
Dogs, 36, 67, 79, 92
Dominance, 76, 78, 86
Dove, 57, 61, 68, 70, 77, 83
Drug addicts, 45
Duncker, 86
Economics, 14, 16, 17, 35, 39
Economist, 36, 48
Education, 13, 14, 15
  material used, 88
  of rats, 67
  programs, 23, 46
  results of, 67, 68
  system of, 25
  See also Learning
Elder, 70
Electricity used, 80
Elimination pattern, 43
Elliott, 81
Emotional elements, 78, 79, 85
Employment, 31, 34, 37
Environment, 13, 14, 25, 61, 62
Epinephrine, 75
Ethics, 17
Ethnic, 34
Ethnologist, 18
Etiquette, 40
Expectancy, 84
Experimental studies, 27, 50, 62, 66, 69, 70-79, 84, 85, 87, 93
Experiments, 19, 24, 26, 50, 58, 61, 64, 69, 74-80, 81, 82, 85, 90
Exploratory tests, 51, 57, 73
Family, 27, 32, 34
Fatigability, 17, 48
Fertilizer, 14, 28, 31
Festinger, 72
Finan, 81
Fitts, 81
Flexibility, 13, 17, 25, 57
Folk lore, 38, 39
Food
  apportionment, 39
  available, 16, 23, 36
  chart, 15
  choice, 61-64, 67, 69, 71, 72, 82, 86
  concrete, 55
  control, 15, 61, 79
  drive, 78, 80
  edible, 41
  enrichment of, 16
  evaluation, 23
  good for us, 88
  ideals, 35
  intake, 55, 56, 62, 63, 64, 75
  meaning of, 86
  natural, 25, 61, 70
  new, 14, 23, 39, 40, 46, 47, 88
  practice, 56
  prefeeding, 71
  quantitative studies, 31, 35
  rejections of, 15, 24, 36, 40, 67, 85
  religion in, 39
  repetition of, 67, 85
  satiation, 71-74, 76-78, 81, 84
  seasonal, 24, 35
  sharing, 77, 78
  strange, 55, 85
  "together," 72
  unfamiliarity, 66, 69

  unit of study, 25
  See also Palatability, Social status
Food, patterns of eating, 16, 35, 36
  cafeteria, 16, 86
  holidays, 39
"Food furnished," 33
Food locker, 32
Food pathology
  anorexia nervosa, 45
  asthma, 45
  cults and fads, 44, 45
  See also Magical use of diet
Foods used
  alfalfa, 65, 68
  baby, 38
  beverages, 31, 36
  bread and flour, 15, 16, 24, 32, 33, 37, 38, 40, 42, 69, 77, 79, 83, 87, 89
  cake, 32, 34
  carbohydrates, 62
  caseinogen, 61
  cereal and grain, 31, 36, 71, 72
  cod liver oil, 64
  coloring of, 83
  eggs, 87
  fats, 62
  feminine, 38
  fish, 33, 37, 39
  flavoring, 65, 66, 68, 69, 83
  fruits, 36, 57, 70, 77, 79, 86
  leftovers, 36, 72, 85
  meat, 25, 32, 38, 44, 47, 89
  milk, 25, 33, 36, 72, 85
  oil, 62, 66, 68
  oysters, 65
  salt, 61, 62, 63
  sodium, 62
  soy soup, 23
  soya, 88
  sweets, 38, 61, 62, 63, 65, 69, 70, 71, 72, 79, 83, 85
  vegetables, 15, 16, 31, 32, 34, 65, 70, 82, 83
  water, 63, 67, 89, 90
  wine, 42
  yeast, 63, 67
Foodways, 14, 16, 27, 28, 31, 47, 48, 57
French, 69
Fritz, 92
Frustration, 75, 76, 78
Gantt, 79
Garbage, 36, 37
Gardens, 32
Gauger, 85
Genetics, 14, 15, 16, 31
Germans, 25, 27
Gillett, 89
Glucose, 75
Government reports, 31
Great Britain, 15, 34, 39
Group decisions, 89, 90
Guhl, 76, 77
Habits, 82
  changing, 14-19, 24, 26, 41, 45, 80, 84, 85, 86, 88, 89, 90, 92
  concepts, 42, 45
  dynamics, 46
  flexibility, 17, 25
  good or bad, 13, 14, 42
  how change, 24, 25, 26
  inflexible, 14, 24
  parental training, 43
  preferential, 69
  study of defined, 13, 16, 17
  traditional, 13, 14
  unit of study, 25
Harlow, 65, 69, 77, 79
Harrell, 92
Harris, 65, 66, 67
Hausman, 63, 71
Head perceptions, 72
Health, optimum, 17
Hellersberg, 48, 57
Hens, 71, 76, 77
Heron, 81
Historical material, 18
Hoarding, 73, 74, 75, 76
Hollinger, 85
Home conditions, 27
Home economics, 23, 56, 58
Homeostasis, 62
Home status, 62
Household equipment, 13, 23, 44
Housewife's schedule, 34
Housing, 13
Hueneman, 55
Human behavior, 23, 25
Human being as unit, 25, 26
Human nature, 18
Hunger, 42, 46, 70, 71, 73, 75, 77, 79, 80, 81, 82, 85, 90, 91
"Hunger and Work in Savage Tribe," 48
Hunt, 74, 75
Ideology, 17, 40, 41
Illinois, Southeast, 48, 57
Illness, 48
Imitation, 86
Immigrants, 37, 58
Income of group, 25
Index, for weight, 81
Individuals, 25, 57, 59, 77
  identification of, 26
Infant experience, 42, 44, 45, 75, 83
Infant feeding, 16, 38, 43, 63

Insects, 68
Institutional practices, 18, 23, 50
Insulin, 16, 75
Intelligence and diet, 92, 93
Interviews, 49, 56, 57, 58, 89
Iowa City, 48
Iowa, University of, 57
Ivy, 62
Jackson, 80
Jews, 39
Jobs, 37
Joffe, Natalie, 58
Jukes, 65, 68
Karn, 91
Kerrett, Rose, 5
Keys, 93
Kindergarten, 86
King, 91
Kinesthetic cue, 84
Kleiber, 74
Labor, division of, 37
Laird, 83
Learning, 56, 67, 75, 80, 90, 91, 92
Leftovers, 36, 37
Lent, 39
Levine, 82
Lewin, Kurt, 48, 57, 68, 85, 89
Liddell, 79
Lund, 87
McCarrison, 91
McCollum, 62, 63, 65
McCord, 73, 76
McGraw, 83
Magical use of diet, 44
Margolin, 80
Marinho, 86
Maslow, 67, 71
Masserman, 75, 80
Material used, 44
Maurer, 92
Maze learning, 91, 92
Meals, idea of, 35, 82
Medical practices, 13, 23, 38, 42
  convalescents, 67
Mental hygiene, 23
Mental performance, 92
Menu, 24, 36, 87
Methods, 13, 18, 23, 34, 48, 52, 55, 58, 61, 72, 79, 81, 83, 84, 89
  check lists, 34, 35, 56, 57
Métraux, Rhoda, 58
Mice, 61, 65
Mittelman, 79
Moir, 83
Monkeys, 70, 74, 77, 79
Morality, 14, 15, 24, 27, 42
Morgan, 73, 75
Motivation, 17, 67, 80, 81, 85, 90, 91, 92
Mowrer, 78
Murphy, 82
Nervous system, 82, 91, 92
Neurosis, 75, 78, 80
New England, 27, 35
Nissen, 70, 77
Nowlis, 77, 78
Nursery school, 64, 85, 86
Nurses, 58
Nutrition
  approach, 15
  Chart, 15
  committee, 56
  education, 15, 89
  evaluation, 31, 32, 33, 35, 47, 89
  knowledge, 36
  principles, 16, 17, 41, 55
  science of, 16, 25
  surveys, 35, 36
  value, 33, 88
Nutritional behavior, 24, 56
Nutritionist, 14, 58
Obese child, 27
Observational studies, 27, 28, 46, 55, 58
Oestrous cycles, 62
Old age. *See* Aged
Olfactory sensitivity, 69, 70, 75, 83, 84
Orient, 31, 88
"Outline of System of Food Habits in Rural Southwest," 57
Palatability, 65, 70, 72, 83
Parasites, 78
Passin, 48, 57
Patterns, 13, 15, 18, 23, 27, 34, 36, 38, 39, 40, 47, 57, 67
  ethnic, 34
  general, 31
  meals and services, 24, 35, 36, 37
  regional, 57
Patterson, 79
Patton, 91
Pavlov frame, 80
Pellets, 72-76, 78
Peptic ulcers, 45
Physiological psychology, 63
Physiology, 14-18, 41, 48, 67, 68, 75, 91
  basic, 63
  hunger, 63
  needs, 61, 73
Pigeon, 92
Pigs, 36, 61, 75
Platt, 83
Poultry, 61
Powdermaker, 56
Preferences, 66, 68, 69-72, 77-79, 83-86, 90

Pregnancy, 16, 38, 39, 41
Preparation of food, 32, 33, 34, 56
Preservation of food, 32, 37
Price, 65
Price of food, 39
Problems, 27, 32, 41, 67, 68
"Problems of Changing Habits," 5, 58
Processing, 13, 28, 32, 35, 44
Production, 13, 16, 23, 28, 31, 36, 37
Protein, 31, 61, 62, 65, 70, 72
Psychiatry, 23, 57
Psychoanalysis, 57, 75
Psychodynamics, 43
Psychology, 14, 17, 18, 19, 23, 26, 27, 57, 67
Psychomotor, 92
Psychophysical, 83
Psychosomatic disorders, 44, 45, 48, 79
Punishment, 68, 78
Purchasing of food, 33, 34, 38
Purchasing power, 16, 17
Queens College, 56
Questionnaires, 23, 28, 34, 48, 52, 55, 56, 57
Questions, to ask, 24-26, 31, 33, 42, 46, 47, 49, 52, 61, 67, 71, 72, 77, 80, 81, 82, 90
Rabbits, 68, 70
Rachitic, 65, 66, 68
Rate of eating, 74, 81
Rationing, 39
Rats, 61-78, 80, 81, 90, 92
Ready, 87
Reality process, 82
Regional variations, 41
Reproduction, 62
Research, 17, 18, 23, 24, 25
Responses, 82
Restaurants, 50
Rewards, 67, 68, 78
Rhythm in eating, 56, 81, 82
Ribble, 75
Rice, 89
Richter, 62, 64, 65, 66
Rickets, 64-66, 68, 91
Roberts, 85
Role of food, 39, 43
Rural, 24, 25, 35, 37, 57
Sanctions, 40, 43, 44
Sanford, 82
Scantlebury, 79
Scarcity of, 36, 39, 57
Schizophrenia, 92
School lunches, 24, 50, 55
Science of, 13, 24
Selection, 17, 28, 61-65, 67-69
Selenium, 65
Sheep, 78, 79
Shopping, 24, 33, 34, 37
Shortages, 16, 23
Skinner, 81
Sladden, 68
Smith, 74
Social agency, 58
Social conditions, 76, 77, 79, 86
Social history, 18, 48
Social pressure, 15, 33, 64
"Social Process and Dietary Change," 57
Social science, 24
Social status, 37, 38, 41, 46
Sociology, 14, 18, 23, 48
Southeast America, 41, 47, 57
Soya, 88
Speech images, 42
Stability, 16, 25, 46, 47
Stature, increase of, 17
Stellar, 74, 75
Stevens, 91
Stomach, 78-81
Stone, 69
Storage of food, 28, 31, 32, 58, 85, 89, 90
Students, college, 48, 58, 85, 89, 90
  historical data, 18
  methods, 55, 56
  objectives, 19, 23, 24, 26, 27, 31, 36, 48, 49
Studies, 18, 19, 27, 35, 36, 42, 47, 48, 49, 56, 57, 65, 69, 71, 82, 83, 86
Sub-cultural groups, 58
  Czechs, 34, 49
  Eskimo, 31
  Italian, 26, 27, 42
  Negro, 49, 57
Substitutes, 46
Surveys, 23, 35, 36, 49
Sweetman, 83
Symbolism, 42
Syrians, 58
Table manners, 40
Taboos, 38, 39, 40
Taste, 32, 63, 65, 83, 84, 86, 88
Taylor, 81
Techniques, 36, 55, 62, 70, 72, 74, 82, 83, 84, 89, 91
Technology, 18, 24, 25, 26, 43
Tests, 52, 57, 69, 70, 72, 73, 74, 82-86
  mental, 92
  projective, 63
Therapeutic measures, 13
Tools, 43
Traditional, 14, 27, 42, 47, 55
Transportation, 13
Turner, 55
Unit of study, 25

United States, 15, 32, 39, 40, 46
Urban, 23, 32, 34, 35, 37, 38, 39, 49
Utensils, 43, 44, 56
Vegetarian, 44, 45
Viosterol, 66, 67
Visual, 83
Vitamins, 15, 16, 26, 32, 45, 48, 66, 91, 92
  Vitamin A, 65, 67, 91
  Vitamin B, 66, 68, 90, 91
  Vitamin B complex, 66, 68, 90-92
  Vitamin C, 48
  Vitamin D, 66, 67
  Vitamin E, 92
  Vitamin G, 65
  Vitamin precursor, 56
Warden, 80
Warkentin, 63
Warner, 80
Water, 90
Weather, 87, 88, 89
Wilder, 65
Willerman, 89
Wittenborn, 66, 68
Wolfe, 73, 75, 79
Workers, 41
Young, 66-74, 81, 89
Yudin, 77, 79

The National Research Council

Membership and Organization.—The National Research Council is a cooperative organization of scientific men of America, including also a representation of men of affairs interested in engineering and industry and in the basic sciences upon which the applications of science depend. Its membership is largely composed of accredited representatives of about eighty-five national scientific and technical societies. Its essential purpose is the promotion of scientific research and of the application and dissemination of scientific knowledge for the benefit of the national strength and well-being.

The Council was established at the request of the President of the United States, by the National Academy of Sciences, under its Congressional charter to coordinate the research facilities of the country for work on military problems involving scientific knowledge. In 1918, by Executive Order, it was reorganized as a permanent body for the general encouragement of scientific research.

BULLETIN
OF THE
NATIONAL RESEARCH COUNCIL
NUMBER 112 JUNE 1945

THE NUTRITIONAL IMPROVEMENT
OF
WHITE RICE

PUBLISHED BY THE NATIONAL RESEARCH COUNCIL
NATIONAL ACADEMY OF SCIENCES
WASHINGTON, D. C.

Announcement Concerning Publications
of the
National Research Council

The Proceedings of the National Academy of Sciences

is partly supported by the National Research Council which is represented officially on its Editorial Board and Executive Committee. It is open for the publication of papers to members of the National Research Council on the same terms as to members of the National Academy of Sciences.

Subscription rate for the *Proceedings* is $5 per year. Business address: Home Secretary, National Academy of Sciences, 2101 Constitution Ave., Washington 25, D. C.

The Bulletin of the National Research Council

presents monographs especially prepared by Committees of the Council or directories for general use in science compiled by the Council.

The *Bulletin* is published at irregular intervals. A discount of 20% from the list price of the *Bulletins* will be given to all who subscribe for the Series as issued, direct from the Publication Office. Numbers of the *Bulletin* are sold separately at prices based upon the cost of manufacture.

The Reprint and Circular Series of the National Research Council

renders available for purchase, at prices dependent upon the cost of manufacture, papers published or printed by or for the National Research Council. A discount of 20% from the list price will be given to all who subscribe for the Series as issued, direct from the Publication Office.

Orders for the *Bulletin* or the *Reprints and Circulars* of the National Research Council, accompanied by remittance made payable to the National Academy of Sciences, should be addressed: Publication Office, National Research Council, 2101 Constitution Ave., Washington 25, D. C.

A list of publications of the National Research Council with prices will be furnished upon request.

BULLETIN
OF THE
NATIONAL RESEARCH COUNCIL
NUMBER 112 JUNE 1945

THE NUTRITIONAL IMPROVEMENT OF WHITE RICE

By
M. C. KIK and R. R. WILLIAMS
For The
Committee on Cereals
Food and Nutrition Board

PUBLISHED BY THE NATIONAL RESEARCH COUNCIL
NATIONAL ACADEMY OF SCIENCES
WASHINGTON 25, D. C.

FOREWORD

Mental and physical health in this country, as in all others, is dependent in large part on the quality of man's food. Since better nutritional welfare is so closely allied with economic circumstances and with traditional food habits, it follows that for widespread dietary improvement some of our inexpensive staple foods must be improved in nutritional quality. It is this philosophy of increasing the quality of simple, economical foodstuffs that has stimulated the Food and Nutrition Board and its Committee on Cereals to take the lead in recommending methods for providing more nutritious flour, bread, and corn food products.

Through the generous cooperation of the Arkansas State Agricultural Experiment Station, M. C. Kik, Ph.D., of its faculty, and Robert R. Williams, Sc.D., Chairman of the Food and Nutrition Board's Committee on Cereals have joined resources in preparing this report on rice. It is published as a National Research Council report with the approval of the Director of the Arkansas State Agricultural Experiment Station. The experimental data presented herein are from the Arkansas Station unless otherwise credited.

Dr. Kik is Associate Professor of Agricultural Chemistry, Department of Agricultural Chemistry, College of Agriculture, University of Arkansas, Fayetteville, Arkansas. Dr. Williams' interest in rice and in improved nutrition is of long standing; he was born in India and his early work in chemistry was with Colonel Vedder in the Philippines where he studied the effect of rice bran on beri-beri patients. Dr. Williams is now Chemical Consultant to the Bell Telephone Laboratories, Murray Hill, New Jersey. He is a member of the Food and Nutrition Board and is Chairman of its Committee on Cereals.

We are making this information on the nutritional improvement of white rice widely available for students of food, agriculture, health, and human welfare, in the hope of increasing both "the quantity and the quality of life."

Frank G. Boudreau, M.D., *Chairman,*
Food and Nutrition Board.

CONTENTS

PAGE

INTRODUCTION . . . 1

RICE PRODUCTION AND CONSUMPTION . . . 2
- In the Orient . . . 2
- In the United States . . . 6
- In Puerto Rico . . . 10
- In Europe . . . 13

RICE COOKERY . . . 14
- China . . . 15
- Philippines and Malaya . . . 16
- Burma . . . 16
- India . . . 16
- United States . . . 16
- Puerto Rico . . . 18
- Losses of Nutrients in Rinsing and Cooking of Rice . . . 18

THE NUTRITIVE QUALTIES OF RICE . . . 23
- Nutritional Status in Rice Areas of Asia . . . 25

POLISHED RICE AND BERIBERI . . . 26

PROPOSED CORRECTIVE MEASURES AGAINST BERIBERI . . . 28

COMMERCIAL MILLING OF RICE . . . 30
- Milling Process . . . 30
- Losses of Nutrients in Milling . . . 39
- Feasibility of Standardized Undermilling . . . 41
- Standard for Unpolished Rice . . . 49
- Earle Process of Undermilling . . . 50

DETERIORATION OF RICE IN STORAGE . . . 51
- Insect Attack . . . 52
- Rancidity . . . 52
- Losses of Nutrients in Storage of Rice . . . 53

PARBOILING OF RICE . . . 58
- Nutrients in Parboiled Rice . . . 60

RICE CONVERSION . . . 61
- Laboratory Tests of Rice Conversion . . . 63
- Studies of Commercial Conversion . . . 64
- Effect of Conversion on Milling Quality . . . 65
- Malek Process . . . 71

ARTIFICIAL ENRICHMENT OF RICE . . . 71

RÉSUMÉ . . . 74

APPENDIX . . . 76

TABLES

PAGE
1. Consumption of Rice in the United States, 1937 9
2. Thiamine in Recent Rice from Puerto Rico 13
3. Annual Consumption and Production of Rice in Various Countries 13
4. Effect of Washing on the Thiamine, Riboflavin, and Niacin Content of Rice 20
5. Effect of Cooking in Excess Water on Loss of Vitamins 21
6. Average Composition of Corn, Rice, and Wheat 23
7. Amino Acid Content of Rice, Corn, Wheat, and Casein 24
8. Recent Prevalence of Beriberi in the Orient 27
9. Average Thiamine, Riboflavin, and Niacin in Rice (Rough, Brown, and White) Harvest 1941, 1942, and 1943 41
10. Thiamine, Riboflavin, and Niacin in Commercial Rice (1942) 42
11. Other Vitamins in Brown and White Rice 44
12. Dependence of Vitamin Content on Degree of Milling 44
13. Comparative Decline of Nutrients during Milling of Rice 46
14. Nutrients in Unpolished Rice 49
15. Thiamine, Riboflavin, and Niacin in "Peeled" Rice 50
16. Stability of Thiamine in Rice in Storage 55
17. Average Losses of Nutrients in Rice During Attic Storage 56
18. Average Losses of Nutrients in Rice in Cold Storage 56
19. Stability of Thiamine in Rice in Storage 57
20. Average Losses of Thiamine in Rice in Storage 57
21. Thiamine, Riboflavin, and Niacin in Milled Parboiled and Milled Raw Rice 60
22. Thiamine, Riboflavin, and Niacin in Raw and Converted Milled Rice 64
23. Comparison of Thiamine, Riboflavin, and Niacin in Milled Rice, Converted vs. Raw (1942) 66
24. Distribution of Thiamine, Riboflavin, and Niacin in Products of Commercial Milling of Converted Rice (1943) 67
25. Percentage Retention of Thiamine, Riboflavin, and Niacin in Converted Rice Before and After Milling 68
26. Effect of Conversion on Breakage in Shelling 70
27. Effect of Cooking on the Nutrient Content of Artificially Enriched Rice 73
28. Effect of Storage on Thiamine in Rice 76

LIST OF ILLUSTRATIONS

FIGURES

PAGE

Fig. 1. Longitudinal Section of a Rice Grain 31
Fig. 2. Rice Shelling Machine 32
Fig. 3. Rice Shelling Machine—Cross Section 32
Fig. 4. McGill Rice Sheller 33
Fig. 5. Engelberg "Huller" for Scouring Rice 34
Fig. 6. Rice Scouring Macnine, Longitudinal View 35
Fig. 7. Rice Scouring Machine, End View 36
Fig. 8. Rice Brush or Polisner 37
Fig. 9. Disc Separator 38

PHOTOGRAPHS

OPPOSITE PAGE

Paddy Fields of Bejraburi, Thailand 1
National Geographic Society, by special permission *National Geographic Magazine*.

Constructing a Field Levee with a Disc Plow in Southern United States 2
Levees follow contours.
Courtesy of Dr. Jenkin W. Jones, U. S. Department of Agriculture.

Sowing Rice by Airplane in California 5
A. Man on main levee marks successive swaths for the plane.
B. Seed floats on the water briefly before sinking.
Courtesy of Dr. Jenkin W. Jones, U. S. Department of Agriculture.

A Field of Young Rice in United States 6
Soon after application of irrigation water.
Courtesy of Dr. Jenkin W. Jones, U. S. Department of Agriculture.

Cutting Rice With a Twine Binder 9
Southern United States.
Courtesy of Dr. Jenkin W. Jones, U. S. Department of Agriculture.

Threshing Rice in the United States 10
Courtesy of Dr. Jenkin W. Jones, U. S. Department of Agriculture.

Rice Terraces in Bañaue, Northern Luzon 13
National Geographic Society. By special permission, *National Geographic Magazine*.

Paddy fields of Bejraburi, Thailand. National Geographic Society, by special permission *National Geographic Magazine*

THE NUTRITIONAL IMPROVEMENT OF WHITE RICE

INTRODUCTION

The fact that beriberi is associated with white (well-milled) rice consumption is familiar to the reading public. It has been established for more than thirty years that if brown rice should replace white in the diet most of the forthright beriberi in the world would disappear. We do not know, however, to what extent this measure would relieve general malnutrition in lands in which beriberi occurs, nor have we sufficient evidence as a basis for adequate supplementary measures. Moreover, though the nutritional merit of brown versus white rice is well established, only slight progress has been made in realizing its advantages among Oriental peoples and this progress has been largely limited to public institutions and labor crews of organized industry. The incidence of beriberi among general civil populations is probably as high as it ever was, though mortality from it has presumably declined through earlier recognition and application of thiamine therapy.

Experience has shown that there are great obstacles to be overcome before preventive measures can be applied for the benefit of Asia's millions. Popular preference for white rice and also its better keeping qualities under tropical conditions of storage and shipment have effectively prevented the widespread utilization of brown or undermilled rice. Parboiling before milling as traditionally practiced in India is known to have kindred nutritional merit, but the product so far has not proved popularly acceptable where parboiling is not traditional. A modern version of parboiling called "rice conversion" has been recently developed, but the advent of the war prevented an extensive trial of it in the Orient. Recent years have also made available synthetic vitamins which might conceivably be incorporated in Oriental diets with excellent effect. None of these measures, however, has reached the stage of mass application to nutritional reform in rice-eating countries. Years of preparatory work may still be required. The application of synthetic vitamins to rice is much more difficult than enrichment of flour. External application will not suffice, for rinsing prior to cooking will remove the added substances. Economic handicaps are also much more severe in most Oriental rice-eating areas than in more highly developed Western countries.

In the United States, rice is a staple for only small segments of the population, chiefly in certain former and present rice-growing areas. In these areas, however, the shortcomings of white rice are nutritionally important and rice growing and milling has a substantial commercial standing. Whatever can be done for the nutritional improvement of rice in the United States will be well justified by benefits to consumers and producers alike within our own borders.

For many reasons the United States at present offers the best field for study of the white rice problem. Only within the past five years have laboratory methods of assay for the several vitamins become available. Facilities for such assay are more abundant in the United States than elsewhere. It is also an advantage that the rice industry in the United States is relatively highly mechanized and there is available some technically skilled personnel. The opportunity for the development of a rather intricate technical process such as rice conversion is certainly more favorable here than in less industrialized countries.

The fact is that, although we have known broadly for many years about the nutritional merits of retaining the vitamins of rice, very few precise data have been accumulated for guidance in commercial processing. For example, we have not known how much bran we must retain in order to conserve sufficiently the essential nutrients or how to do so with the least sacrifice of appearance and keeping qualities. We must learn how to set our hullers and brushes to achieve the best result and then determine whether this is sufficiently good from a public health standpoint. We must also know the extent of spoilage in storage and how to prevent it.

It is the purpose of this bulletin to collect, as far as possible, the essential facts that indicate the relative promise of each of the various expedients to improve the quality of milled rice and furnish criteria for future commercial practice. It is hoped that the rice industry of the United States will make profitable use of the information and find one or more practical solutions of the nutritional problem that rice presents. If the American rice industry can solve the problem it will not only insure its own future but also furnish guideposts for the larger and more difficult problem in the Orient.

RICE PRODUCTION AND CONSUMPTION

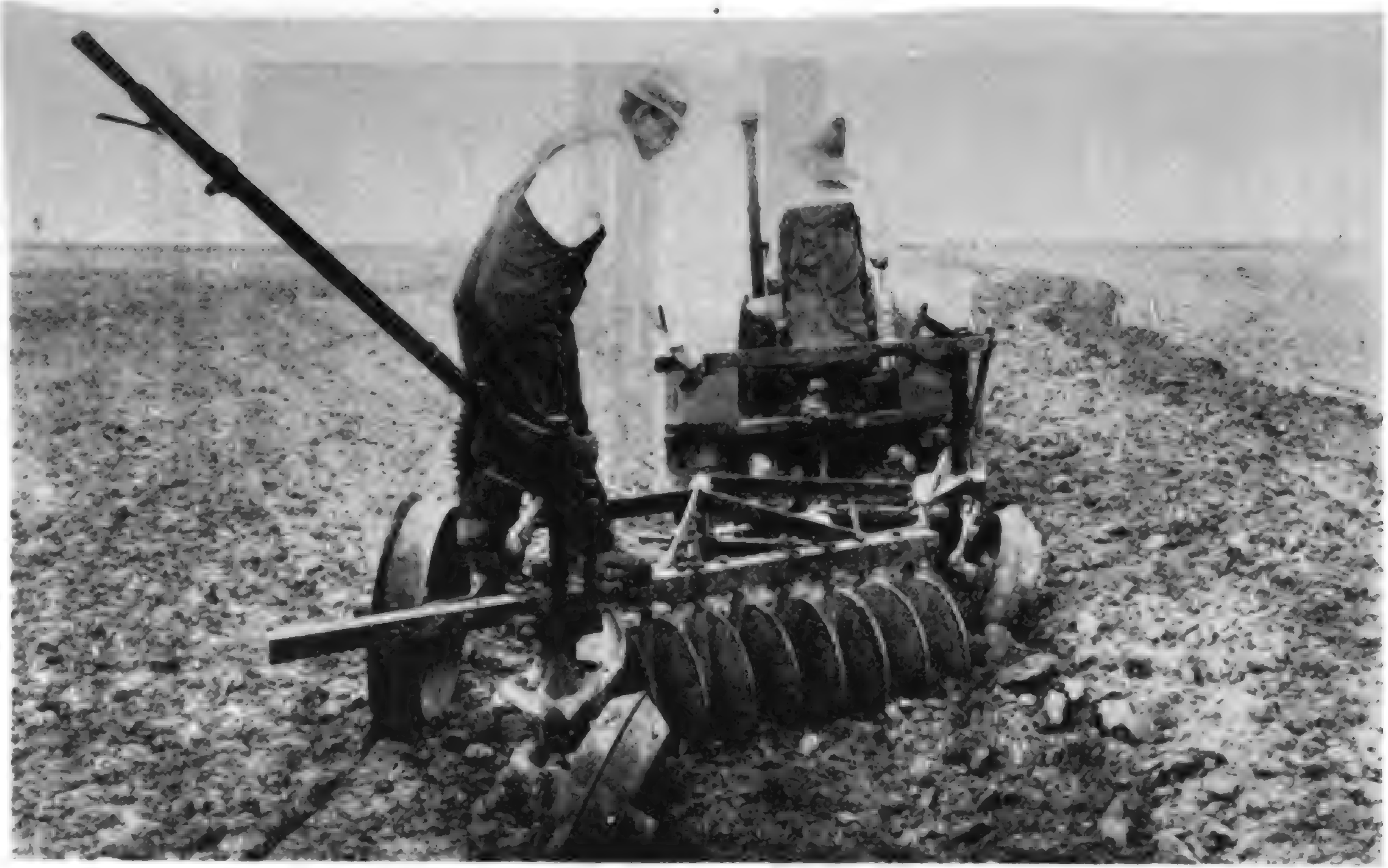
In the Orient[1]

Rice *(Oryza sativa L.)* is the great source-of-energy food of hundreds of millions of people in the Orient, including notably: China, French Indo China, Thailand, Burma, British Malaya, India, Ceylon, Philippines, Netherlands Indies, and Japan. Here 95 percent of the world's rice is produced and consumed. Rice probably originated in the southeastern part of Asia and was certainly known in India and China by 3000 B.C. In many Asiatic languages, rice and food are synonymous and in classic Chinese the term for "agriculture" is "rice culture." There are a dozen or more wild species of rice, but all cultivated varieties, of which there are several thousand, are of the species *Oryza sativa.* The wild rice of the United States *(Zisania aquatica)* is not a true rice. While the cultivated varieties of rice present a great range of characteristics, the most distinctive derivations from the common pattern are the glutinous rices. These are so called because they become very sticky when cooked. They are popular for special uses in various Oriental countries but are produced in minor volume. In parts of China perhaps 20 percent of the local supply is of this type.

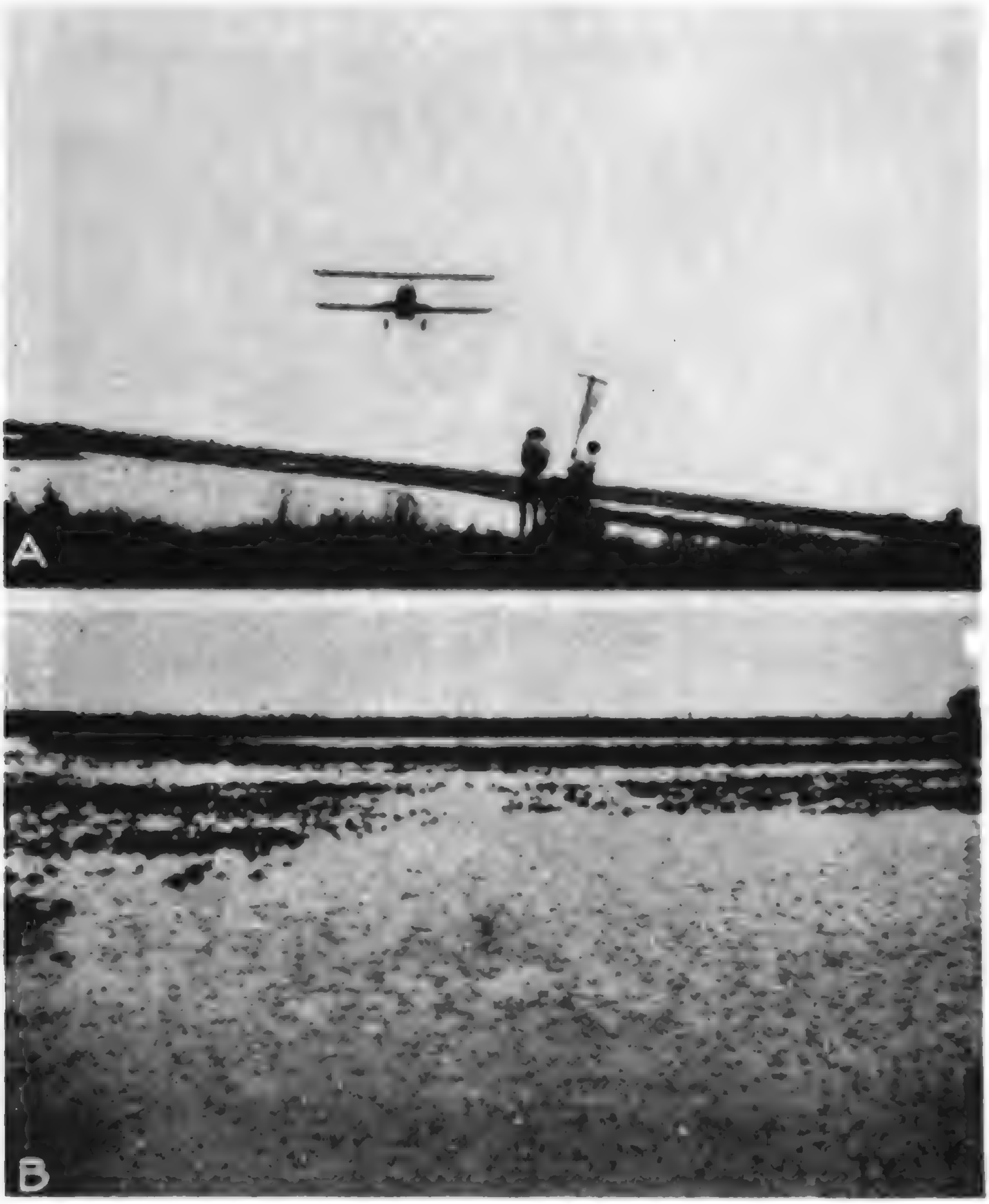
All but a small fraction of the world's supply of rice is produced under

---

[1] Wickizer, V. D., and Bennett, M. K.: The rice economy of Monsoon Asia. Food Research Institute, Stanford University, California, 1941: 358 p.



Constructing a field levee with a disc plow in Southern United States. Levees follow contours. Courtesy of Dr. Jenkin W. Jones, U. S. Department of Agriculture



Sowing rice by airplane in California. A. Man on main levee marks successive swaths for the plane. B. Seed floats on the water briefly before sinking.
Courtesy of Dr. Jenkin W. Jones, U. S. Department of Agriculture

irrigation and the product of this type of culture is called lowland rice. Upland rice is grown without irrigation on slopes or level land where rainfall is fairly high. Upland acreage, as well as upland yield per acre, is much less than lowland in all countries where rice is an important crop. During two or three months at the height of its growing season, lowland rice requires water in an amount equal to 15 to 30 inches of rainfall per month, depending on the extent of seepage, evaporation, etc. The fields are leveled and diked to provide for uniform submergence of the land. In broad flat valleys, the labor of leveling and diking is relatively low; on hillsides, extensive terracing may be necessary to provide small level patches. The culture of rice is accordingly a highly specialized form of agriculture. Yields per acre reach 30 barrels (162 pounds) under favorable conditions. Asiatic yields average about 12 barrels per acre.

Of a total world production of 95.6 million tons, 90.9 million tons of rice are produced in the Orient; 4.7 million tons in all other parts of the world, including the United States. Thirty-seven percent of the Oriental production is in China, 27 percent in India, 9 percent in Japan, and lesser percentages in other countries. The heaviest per capita consumption of rice is localized in Southeastern China, where it is said to be from 400 to 548 pounds per year. It falls below 10 pounds per year in wide regions of northern China and northwestern India, where the climate is not adapted to rice culture. In India, figures for the southern and eastern provinces range from 221 to 405 pounds; in other provinces the range is from 0 to 98 pounds. Chosen or Korea has a consumption level of 125 pounds. Java has an average of 200 pounds per capita, higher in the west and considerably lower in the east. Some 630 million Orientals derive more than 40 percent of their total food calories from rice; some 310 million Eastern people are non-rice eaters.

The international trade in rice remains, even in peacetime, mainly within the borders of Asia; less than one-third of the exports of Asia go outside of this region. Export countries are Burma, Thailand, Korea, and Indo China. Rice normally is imported to Japan, India, British Malaya, Ceylon, China, and Netherlands Indies, in volumes descending in the order named. Within each country domestic rice moves in trade from one region to another, from areas of surplus production to deficit and non-producing areas.

Where rice is grown primarily for local use rather than for export, the grower and his neighbor on farms and in nearby villages often secure their rice in paddy form and day by day pound off the hulls in mortars by hand at their homes as food is required. While well-milled white rice can be and often is produced by this primitive means, the tendency is for the home-pounded product to be undermilled. In areas where rice is grown extensively, machine milling predominates and relatively highly milled white rice is largely used even locally. In most cities rice comes exclusively from commercial mills and is highly milled. As industrialization proceeds in the Orient the hand mortar is replaced increasingly by machine milling except in remote areas. The use of parboiled rice, especially in India, is discussed on page 58. In the Dutch East Indies much rice is said to be consumed in brown form.

In the United States

Rice was introduced in the United States in 1685 at Charleston, South Carolina, and is now cultivated as lowland irrigated rice in Louisiana, Arkansas, Texas, and California. But little rice is now grown in South Carolina; it is upland and not irrigated. The estimated rice crop[2] of the United States in 1944 amounted to 19 million barrels (162 pounds), an increase of 95 percent during ten years. It is, however, less than 2 percent of the world production. Thirty percent of this commercial rice was grown in Louisiana; twenty odd percent was produced in each of the three states, Arkansas, Texas, and California. The average yield for the United States, as for the Orient, is about 12 barrels per acre. (One barrel=3.6 bushels.)

The method of culture is adapted from that of the Orient where hand labor is cheap and abundant. Under our labor conditions mechanization was indispensable to the extension of rice culture in the United States and great ingenuity has been displayed in this development. While rice for lowland planting in the Orient is sown in seed beds and seedlings are transplanted by hand into the flooded paddies, mostly by women and children wading in the mud and water, such use of labor in the United States would be impossible. Accordingly, the American practice is to prepare the land and drill in or broadcast the seed essentially as in the planting of wheat. Plowing and drilling is done over the tops of the low subsidiary dykes or levees. After the land is seeded, the levees are restored by a special plow and drag and the land is lightly flooded if necessary to promote germination of the seed. The excess water is drained off till the rice has grown to 4 or 5 inches in height, when the soil is again flooded and kept flooded for 2 to 3 months or till the grain is almost mature. The depth of water is maintained at 2 inches in the early stages of growth and at 4 to 5 inches at the later stages. Two or three weeks before harvest the land is drained and allowed to dry to facilitate the use of harvesting machinery. The binder is in most common use for harvesting.

The shocked rice, after two weeks or more of curing, is threshed like wheat. The "combine" is replacing the binder and thresher in the present manpower shortage. The use of the combine necessitates the installation of driers in rice-producing communities, as the "combine" rice has an excessive moisture content that would otherwise promote spoilage in storage of the threshed grain. By drying from 22 to 25 percent moisture down to 12 to 14 percent, spoilage is avoided. Except for flooding, the methods and machinery in all essential phases of rice culture are similar to those used in wheat production.

In California, rice culture is provided with a somewhat wider range of implements than in other states. There the ground is often fully prepared, the levees are fully formed, the land is flooded, and the seed is sown on the water by airplane.

Rice culture, like sugar culture, is a protected industry in the United States. There is a customs tariff of 2.5 cents per pound on milled rice imported into the United States and its possessions. The effect of this has been abated

---

[2] Reid, W. M. Estimate of the rice crop for the year 1944. The Rice Millers' Association, New Orleans, La.

A field of young rice in United States, soon after application of irrigation water. Courtesy of Dr. Jenkin W. Jones, U. S. Department of Agriculture

Cutting Rice With a Twine Binder, Southern United States. Courtesy of Dr. Jenkin W. Jones, U. S. Department of Agriculture

TABLE 1
CONSUMPTION OF RICE IN THE UNITED STATES, 1937

State	Population	Per Capita (Pounds)	Total Consumption (Pounds)
Alabama	2,646,248	9	23,814,000
Arizona	435,573	2	872,000
Arkansas	1,854,482	5	9,270,000
California	5,677,251	9	51,093,000
Colorado	1,035,791	2	2,072,000
Connecticut	1,606,903	1	1,607,000
Florida	1,468,211	20	29,360,000
Georgia	2,908,506	20	58,180,000
Idaho	445,032	1	445,000
Illinois	7,630,654	2	15,262,000
Indiana	3,238,503	2	6,478,000
Iowa	2,470,939	2	4,942,000
Kansas	1,880,999	2	3,762,000
Kentucky	2,614,589	2	5,230,000
Louisiana	2,101,593	40	84,200,000
Maine	797,423	1	737,000
Massachusetts	4,249,614	3	12,750,000
Maryland	1,631,526	2	3,264,000
Delaware	238,380	2	476,000
Michigan	4,842,325	2	9,684,000
Minnesota	2,536,953	2	5,128,000
Mississippi	2,009,821	5	10,050,000
Missouri	3,629,367	3	10,887,000
Montana	537,606	1	538,000
Nebraska	1,377,963	2	2,656,000
New Hampshire	465,293	2	930,000
New Jersey	4,041,334	3	12,123,000
New Mexico	432,317	1	423,000
New York	12,588,066	3	37,764,000
Nevada	91,058	2	182,000
North Carolina	3,170,276	20	63,400,000
South Carolina	1,738,765	20	34,780,000
North Dakota	680,845	1	681,000
Ohio	6,646,697	3	19,941,000
Oklahoma	2,696,040	5	11,980,000
Oregon	953,786	3	2,862,000
Pennsylvania	9,631,350	5	48,155,000
Rhode Island	687,497	2	1,374,000
South Dakota	692,849	2	1,386,000
Tennessee	2,616,556	3	7,851,000
Texas	5,824,715	10	58,245,000
Utah	507,847	2	1,016,000
Vermont	359,611	2	720,000
Virginia	2,421,851	3	7,266,000
Washington	1,563,396	4	6,252,000
West Virginia	1,729,205	5	8,645,000
Wisconsin	2,939,006	2	5,878,000
Wyoming	225,565	2	452,000
	122,290,000	5.6	685,123,000

locally to a minor extent by reciprocal trade treaties between the United States and various Central and South American countries during the past 5 years.

In Table 1 the per capita consumption for 1937, as furnished by Mr. G. A. Collier,* is given by states and for the nation as a whole. The average per capita consumption in 1937 amounted to 5.6 pounds per year. Louisiana, the leading rice-producing state, had an average consumption of 40 pounds; in the rice-growing districts in this state the consumption is from 90 to 100 pounds per capita, while in the northern part from 25 to 30 pounds per capita per year are eaten.[3] Relatively large average consumptions for the United States of 20 pounds per capita are found in Florida, Georgia, and the Carolinas, where little or no rice is now produced. While the per capita consumption is large in the Gulf and Southern states, it is by no means uniform in those regions. It is heaviest along the coast and diminishes inland. In some states, where the overall average per capita consumption is slight, there are certain sections in which it is relatively large.

The United States production far exceeds the domestic consumption. A fourth of the crop goes to Puerto Rico, Hawaii, and Alaska; a fifth is exported, now mainly to Cuba.

In Puerto Rico

In Puerto Rico (population, two millions) the rice consumption amounts to 140 pounds a year per person, of which approximately 2 percent is produced locally. The rice formerly consumed was almost entirely milled white rice, but there are at present tendencies in the United States to mill rice somewhat less and to sell an undermilled rice. Undermilled rice has long been preferred in Cuba, which until 5 years ago received its supply largely from the Orient. Relatively little beriberi has been seen in Cuba; Puerto Rico, on the other hand, is known for its generally bad nutrition. A great deal of beriberi has been reported there in the past, where highly milled rice from the United States has been imported for years because of the tariff on rice from other countries. It is felt that a change from milled white rice to undermilled rice or to specially processed rice (pages 58-71) will be of benefit to the people of Puerto Rico.

Because of the responsibility of the United States for the welfare of Puerto Rico we have examined its rice problem in a special way, as is indicated in the following and in some of the subsequent passages.

It is impossible now to estimate accurately the quality of rice previously supplied to Puerto Rico. However, several samples of milled rice were obtained from Puerto Rican retail stores in 1943 and tested for thiamine content. The results of these tests are given in Table 2.

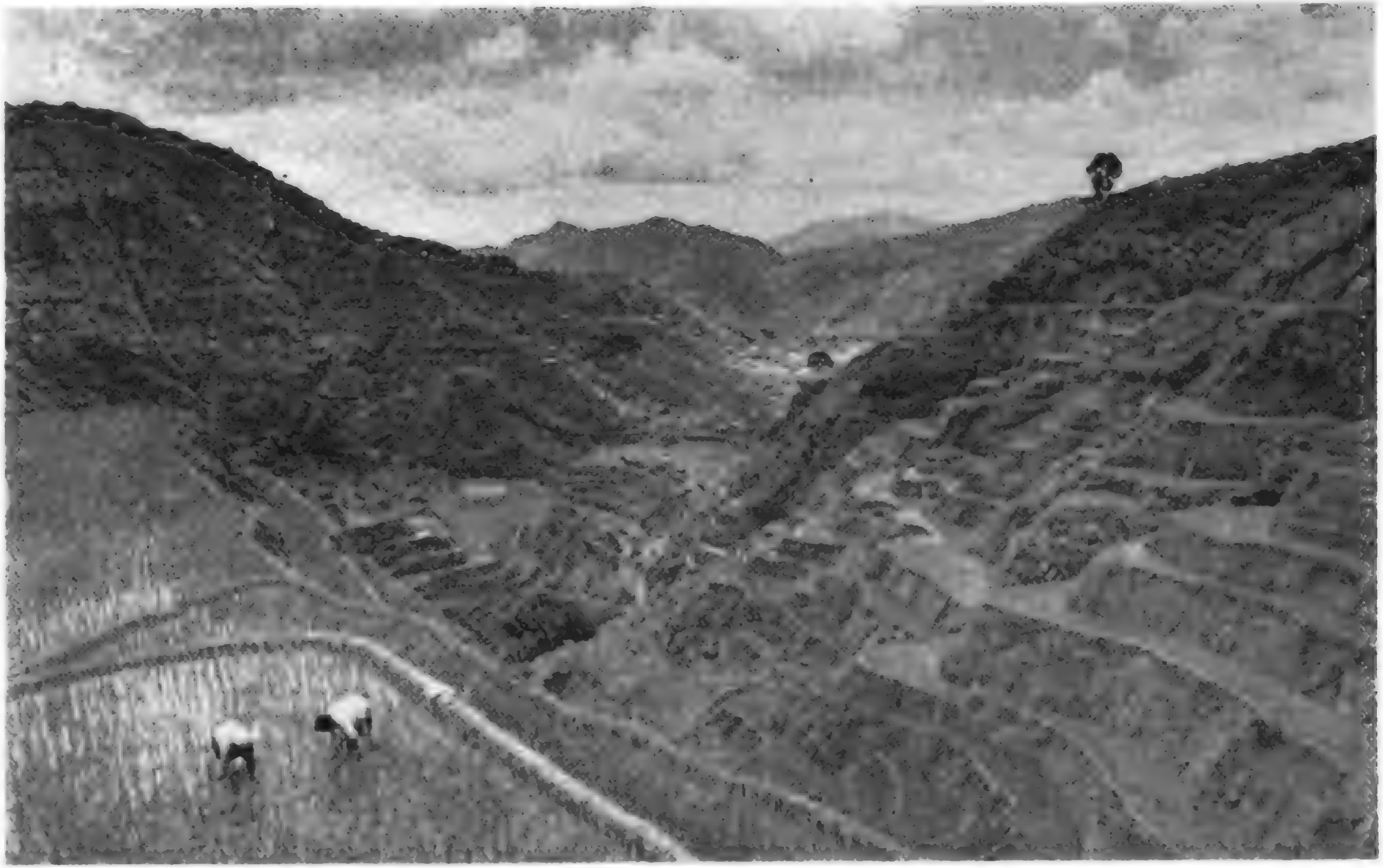
The rice recently shipped to Puerto Rico, represented by the analyses in Table 2, is obviously undermilled and furnishes more thiamine than that customarily consumed before the war. One pound of undermilled rice, such as

---

* Grain Products Branch, War Food Administration, Washington, D. C.

[3] Personal Communication of Mr. W. M. Reid, Executive Vice President, Rice Millers' Association, New Orleans, La.

Threshing rice in the United States. Courtesy of Dr. Jenkin W. Jones, U. S. Department of Agriculture



Rice terraces in Banaue, Northern Luzon. National Geographic Society. By special permission, *National Geographic Magazine*

TABLE 2

THIAMINE IN RECENT RICE FROM PUERTO RICO

	µg/gm		µg/gm
San Miguel A—Blue Rose	0.90	Blue Rose Lara	1.00
Cavadonga—Prolific Mixed	0.85	Dominican rice	1.10
San Miguel A—Long grain	1.00	Lara—Choice Japan California	1.09
San Miguel A—Long grain Rexora	0.90	Andrade—Long grain	1.09
Puerto Rican	1.09	Cavadonga—Blue Rose Mixed	1.00
Lara—Long grain	1.05	Cavadonga—Long grain	1.09
San Miguel #2—California rice	0.91	Blue Rose Lara	1.00

Puerto Rico now appears to be receiving, furnishes about 0.5 milligram of thiamine or about twice as much as highly milled rice. Since losses take place in rinsing before cooking and since there is a limited supply of vegetables and lean pork, which furnish thiamine, it is felt that this is inadequate insurance against thiamine deficiency. However, the change from the use of highly milled rice to that of undermilled rice is commended as useful.

A sample of Puerto Rican paddy or rough rice contained 3.40 micrograms of thiamine per gram, which is approximately the average for United States varieties of rough rice (page 41).

In Europe

In Europe rice is a grain of prime importance only in Italy and Spain. Egypt is an important consumer. An idea of its production and consumption in these parts of the world is given in Table 3.

TABLE 3

ANNUAL CONSUMPTION AND PRODUCTION OF RICE IN VARIOUS COUNTRIES[a]

Country	Per Capita Consumption Pounds	Per Capita Production Pounds
United Kingdom	6.20	None
France	8.90	None
Germany	11.20	None
Holland	5.10	None
Denmark	4.40	None
Sweden	1.90	None
Italy	13.80	22
Spain	14.50	18
Austria	10.03	—
Norway	1.80	None
Roumania	3.20	—
Portugal	5.00	approx. 5
Greece	10.00	None
Poland	5.50	—
All Europe (est.)	7.30	—
Egypt	25.90	51
Russia	1.10	0.05

---

[a] From the *Rice Journal*, July 1931.

RICE COOKERY

Methods of cooking rice are of considerable importance with respect to the nourishment derived from the grain, particularly where it constitutes a prime staple. It would be apart from the purpose of this publication to consider the great variety of rice dishes used in various parts of the world, but it is useful to note the modes of staple cookery in areas where rice is extensively used.

Plain boiled rice is the form in which rice is chiefly used. An objective in its preparation that is sought by people in many lands is the avoidance of stickiness in the cooked grain, so that it will not cohere in compact masses but the grains will remain loose and free. Many expedients are used to accomplish this purpose, some of them extremely detrimental to the nutritional quality of the rice. These expedients are summarized and explained:

1. Rinsing of the raw rice before cooking. This serves to remove the fine starch that is readily solubilized during cooking and thereby adds to stickiness.
2. Methods of cooking:
    (a) Large amounts of water are used and the excess drained away, carrying with it most of the starch which has been rendered soluble.
    (b) The rinsed raw rice is immersed in water just sufficient to swell the grains properly and cooked in a double boiler or over a slow fire, to avoid burning at the bottom, till the water is fully absorbed.
3. Rinsing of the cooked rice. This is often resorted to in order to remove further the films of soluble starch on the surface of the grains.
4. Rice is in some cases partly cooked according to 2a. After draining off the water, the half-cooked rice is steamed to a state of tenderness by supporting it in a pan or basket in an enclosed space over freely boiling water.

Rinsings and decantations of cooking waters profoundly deplete the nutrient contents of the rice as is shown in detail on pages 18-22. This is so much the case that the mode of cooking becomes one of the prime considerations governing the feasibility of effective nutritional improvement of white rice. Peoples who persist in drastic rinsings and in discarding of cooking water will of necessity sacrifice a large part of any nutritional improvement that can be achieved with present known methods. The situation is somewhat analogous to that of the proposed enrichment of macaroni and spaghetti for the use of people of Italian origin in the United States. The customary discards of cooking waters from these foods are so large as to cause a loss of nearly half the nutrients added. For enrichment to be equally effective, the nutrient additions must be nearly twice as great as in enriched flour or bread.

In the Orient, where rice is the chief source of calories for many millions of people, avoidance of stickiness in boiled rice is doubly prized. Especially is this true in India, Burma, and other South Asiatic countries where rice is often eaten with the fingers. The variety of the rice used has some influence upon its cooking quality; for example, the long-grained varieties popular in India are less prone to become sticky than the short-grain varieties preferred in Japan. Fortunately, cooking without discard of water is prevalent, though not universal, in most of these lands. Some details of prevalent customs are summarized below.

Rice Cookery in Various Countries:

China. We are indebted to Mr. Hsi Hsiang Chen,[4] Counsellor of the Ministry of Food of the Chungking Government, for the following information. Rice is the staple food of most Chinese who dwell in the Yangtze valley or south of it, living within 800 to 1000 miles of the sea. Along the sea coast and especially in and about the port cities, the Cantonese method of cooking rice is most popular and use of this method is growing. The Cantonese method employs for cooking a volume of water equal to that of the raw rice or perhaps one and one-half times as great. The rice is cooked over a slow fire in a thick-walled iron or clay pot till all the water is absorbed. The resulting rice is loose and free and, like most solid foods, is eaten with chopsticks. The losses of nutrients in such cooking of rice are negligible. However, there are significant losses due to rinsing, which precedes cooking by the method above described. Mr. Chen is of the opinion that the Cantonese method applies to only 10 to 15 percent of the rice consumed in China; others incline to a higher figure.

Another method that is desirable also from a nutritional viewpoint is the use of rice in gruel form, which in Mr. Chen's opinion applies to 20 to 30 percent of China's rice consumption. This method is regarded by the Chinese as the most economical, since the greatly swollen and softened grain fills the stomach and is most fully utilized by the body. Rinsing of rice for gruel making is not generally practiced. This results in a further economy of nutrients. However, consumption of at least the noonday rice in grain form is considered desirable from the standpoint of palate appeal.

Mr. Chen assumes that 50 to 70 percent of China's food rice is steamed somewhat according to method 4 (page 14). After boiling briefly in 3 parts of water, the rice is drained and transferred onto a bamboo grill supported in a wooden cylinder. The lower end of the wooden cylinder rests in boiling water above which is the rice resting on the grill and exposed to the steam till it is fully cooked. Choice of the proper wood for the cylinder is thought important for its flavoring effect on the rice. It is unfortunate that this most undesirable method should be so popular.

Comments by Dr. Frank Co Tui[5] of New York University Medical School tend to confirm the opinions of Mr. Chen. Dr. Co Tui mentions the practice in Amoy of straining the cooked rice through a sieve and using the starchy fluid as a liquid food. In this area, lentils or sweet potatoes are often cooked with rice.

---

[4] Private Communication.

[5] Private Communication.

Philippines and Malaya. It is difficult to generalize about so vast a region as that occupied by the Malay peoples. However, it appears that rice is generally rinsed before cooking and that much of it is cooked without excess of water as in the Cantonese method above described. Sometimes a moderate excess is used and this is drained off when the rice is half cooked, often for feeding to smaller children or to domestic pets. The drained rice is then cooked further over a slow fire to the desired loose consistency. Malayan cookery on the whole conserves the food values better than does the Chinese, excess water being discarded much less frequently.

Burma. According to a private statement of Mrs. C. E. Chaney, long a resident of Southern Burma, rice is washed thoroughly, often with seven or eight changes of water, and "is then put into a clay pot of boiling water, the water being in great excess of the rice." After the minimum amount of boiling (five to eight minutes), sufficient to soften the interior of each grain, the pot is thoroughly drained. The pot, closely covered, is then placed near the fire and thus steamed for a long time. Every ten minutes or so the covered pot is inverted and shaken well. The cover is raised momentarily to release the steam and the pot is replaced with another side near the fire. The cooking water is usually thrown away, though it contains enough starch to form a solid gel when cold.

Mrs. F. T. Strait describes rice cookery in the hills of Upper Burma in remarkably similar terms. She says, however: "Usually most of the water is used in the cooking but not all, as they drain the rice before it is thoroughly cooked." Mrs. H. W. Smith, also speaking of the Kachins of Upper Burma, refers to steaming in cane baskets above boiling water as a familiar practice with some families; others cook rice "with the small amount of water needed to do the job and be absorbed when done."

India. Indian practice in rice cookery appears to be extremely varied and it has not been possible to secure an estimate of the relative prevalence of different methods. Banerjee[6] states: "In the ordinary process of cooking rice, the rice is boiled with water and the excess water is thrown away as waste." On the other hand Swaminathan[7] offers the following: "Methods of cooking rice in India vary in different communities and districts; it is often the practice to use as little water as possible and the 'conjee' (rice water) is often taken. On the other hand rice is usually washed before cooking, and washing is regarded as essential by the rice-eating population. The losses from washing are thus more important and constant than the losses from cooking."

United States. We shall concern ourselves with methods of cooking only in the states of high rice consumption. Here rice is used in many ways, but most of all as a basal accompaniment to a meat dish much as potatoes are served in other parts of the United States. In the coastal areas of the

---

[6] Banerjee, S. Losses of protein and minerals in cooked rice. Science and Culture, 5: 262 (1939).

[7] Swaminathan, M. Effect of washing and cooking on nicotinic acid content of raw and parboiled rice. Indian Jour. Med. Research 29: 83-88, (1941).

Carolinas, Georgia, Louisiana, and Eastern Texas, rice appears on the table daily at one or more meals. A staple dish of wide use, both in Southern Louisiana and the coastal Carolinas, is the combination of rice and black-eyed peas (or beans) cooked separately but served together. The rice-peas combination is known as "hoppin' John," especially in the Carolinas. Other leguminous seeds may replace the usual black-eyed peas or red beans. Other vegetables as well as meat juices often provide sauces or gravies for rice. In Louisiana rice is often eaten with milk but without sugar for breakfast and supper.

Those familiar with southern customs, among them Miss Myra Reagan, Miss Ellen LeNoir, and Dr. Hilla Sheriff, give us to understand that there is a tendency throughout the South for the negroes to cook their rice without an excess of water. This is also the general practice of all classes in Southern Louisiana (except in New Orleans) and Eastern Texas. However, the practice of cooking the rice in a large excess of water is generally prevalent among the whites of the Carolinas and in parts of Texas. Steaming after partial cooking in an excess of water is also very popular in the Carolinas. Throughout the South, rice is usually rinsed by all classes before cooking, and rinsing after cooking is widely prevalent except in rural areas surrounding New Orleans.

In the fall of 1943, a survey * was made of rice consumption and cooking practices in the State of Arkansas. This survey was limited to eighteen counties, fourteen of which are in the rice-growing areas and four in the non-rice-producing districts. The average rice consumption per year per person in the four non-rice-producing counties was 5.45 pounds compared to an average consumption of 5.83 pounds in the fourteen where rice is produced.

Open vessel cooking with excess water and double boiler cooking in a minimum of water were equally used. Half of the consumers washed the rice three times before cooking. Forty percent of the rice eaters discarded the cooking water. Rinsing of the cooked rice took place in thirty percent of the cases. From these practices it appears that little thiamine is left in the white milled rice finally used for human consumption. The extent to which losses occur during washing, cooking, and rinsing are discussed elsewhere (pages 18-22).

The average time of soaking of rice before cooking reported in this survey was more than four hours and this soaking took place in 33 percent of the cases. The extreme soaking time was twelve hours. It is not certain whether such soaking is detrimental. According to Van Veen,[8] the water-soluble vitamins penetrate deeper into the kernel through soaking and are less easily lost during careless handling in cooking.

---

*Credit is due to the Extension Service of the College of Agriculture, University of Arkansas, Fayetteville, Ark., for their cooperation in conducting this survey.

[8] Van Veen, A. G. De invloed van wasschen en stoomen op het B_1 vitaminegehalte van rijstsoorten van verschillenden slijpgraad. Geneeskundig Tijdschrift voor Nederlandsch-Indie, 73: 945-957 (1933).

Puerto Rico. In Puerto Rico,[9] some rice is used in the preparation of special dishes, but most of the rice is either plain boiled or stewed. Rice is rinsed about two or three times before cooking. Plain boiled rice is rice cooked in water with salt and lard added and is usually eaten with stewed beans or peas. Salt pork is often used in the place of lard. Stewed rice is rice cooked with annatto lard (manteca de achiote) which gives it an orange color. Poor people sometimes stew rice with salt, water, and annatto lard. However, rice is usually stewed with a "sofrito" and a legume or with a "sofrito" and meat or fish product.

In cooking rice, two methods are used. In the first method, white rice is added to boiling salted water and allowed to boil uncovered until a large amount of water has been absorbed by the rice. Lard is then added, the rice is stirred a little and then covered and allowed to cook over a low flame.

In the second method, fat is first melted, rice is added and slightly fried. Water is added and the rice is boiled until it has absorbed a large amount of water. It is covered and cooked slowly over a low flame. The first method is used in the preparation of stewed rice. Both methods are used in the preparation of plain boiled rice. Water is added as needed for the desired consistency and no water is poured off after the rice is cooked.

Losses of Nutrients in Rinsing and Cooking of Rice.

McCarrison and Norris[10] found that washing of rice causes a great loss of minerals and of thiamine. These authors were of the opinion that the occasional occurrence of beriberi in spite of the use of parboiled rice is due to the practice of washing the rice prior to cooking.

The effects of repeated washing and of boiling on the thiamine content of rice milled by the usual method have also been studied by Van Veen[5] and others. They also reported considerable losses; it has been said by some investigators (Van Veen 1940)[11] that the manner of washing and cooking can be of greater importance than the degree of milling. Particularly, the discarding of the water in which the rice is boiled should be prevented, since it involves the loss of valuable materials.

Aykroyd[12] reports that the average losses of thiamine and niacin during washing and cooking of raw milled rice are from 40 to 50 percent and Swaminathan[7] found that raw rice samples lost an average of 60 percent of niacin on first washing; the second and third washings did not remove much. Parboiled rice samples lost only 12 percent of their niacin; even washing three to four times failed to remove more than 16 percent. Niacin analysis methods of that period were not well adapted to cereals, but these results are considered indicative in a relative sense. The losses caused by cooking alone depend on whether the cooking water is discarded or not. The losses are small if only as much water is used as will be absorbed by the rice in cooking. The prevailing practices of washing and cooking rice result also in appreciable losses of protein and phosphorus. Parboiled rice loses less of these constituents during these manipulations.

---

[9] Mrs. Josefina de Royo, assistant nutritionist, F.D.A., San Juan, Puerto Rico, furnished the information regarding food habits in Puerto Rico.

[10] McCarrison, R. and Norris, R. V.: The relationship of rice to beri-beri in India. Indian Medical Research Memoir No. 2 (1924).

[11] Van Veen, A. G.: De rijstkwestie, Geneeskundig tijdschrift voor Nederlandsch-Indie, 80: 1696-1704 (1940).

[12] Aykroyd, W. R., Krishnan, B. G., Passmore, R., and Sundararajan, A. R.: The rice problem in India, Indian Medical Research Memoir No. 32 (1940).

[7] *Supra.*

The use of unwashed rice for the prevention of beriberi in India has been advocated by Platt.[13] He implies that the need for washing can be eliminated if polishing powders, such as glucose and talc, are abolished. However, the use of such powders has not been encountered in recent literature by the present authors except in Spain, Italy, and the United States, where their use is very limited. Platt states that storage of the brown rice in hermetically sealed containers prevents development of undesirable flavors and that no washing is required with this good storage. He also recommends milling of rice shortly before consumption. He regards improvement of the cleanliness of mills and storage places as important, since washing is unnecessary in case of clean milled rice of good commercial quality; the milling is in itself a cleaning process.

Washing and cooking experiments were performed by one of the authors (M. C. Kik). The data on losses of thiamine, riboflavin, and niacin in washing brown, white, white (enriched), parboiled (Malekized and Converted, see pages 71 and 61) and Earle (undermilled) rice are presented in Table 4. The methods of analysis are described on page 40. One cupful of rice was covered with one cupful of water and stirred and the supernatant liquid discarded. This was repeated twice.

Brown rice so treated lost 21.14 percent of its thiamine, 7.70 percent of riboflavin, and 13 percent of niacin. The losses in milled white rice were higher. Such rice lost 43 percent of the thiamine, 25.92 percent of the riboflavin, and 23.04 percent of the niacin that it contained. The losses of thiamine in rice superficially enriched with thiamine ranged from 45 percent to 75 percent, depending on the degree of enrichment. The high losses are due to the fact that the water-soluble thiamine has been put on the surface of the grain and is easily removed during the washing. Malekized (parboiled) rice lost 15.42 percent, and converted and undermilled rice each lost 6 percent of their thiamine. Both the parboiled and undermilled rice samples lost less thiamine during washing than the brown rice and the enriched rice. Riboflavin and niacin losses in the milled white rices amounted to more than 20 percent and were higher than those of parboiled rice and of brown rice. Malekized and converted rice have lower losses during washing. This is a confirmation of an observation made by Swaminathan[7] on parboiled rice.

In another set of experiments a study was made of the effect of the volume of water used in cooking on the loss of thiamine, riboflavin, and niacin in

---

[13] Platt, B. S. Nutrition in the Colonial Empire. Economic Advisory Council Report. App. 6, p. 786.

[7] *Supra.*

TABLE 4

EFFECT OF WASHING ON THE THIAMINE, RIBOFLAVIN, AND NIACIN CONTENT OF RICE

Type of Rice	Thiamine			Riboflavin			Niacin		
	Before µg/g	After µg/g	Loss Percent	Before µg/g	After µg/g	Loss Percent	Before µg/g	After µg/g	Loss Percent
Brown	4.40	3.47	21.14	.65	.60	7.70	54.00	47.00	13.00
White	.65	.37	43.07	.27	.20	25.92	20.57	15.83	23.04
White (spray enriched)	1.40	.77	45.00	.29	.23	20.70	19.50	15.03	22.92
White (spray enriched)	3.00	.70	70.00	.28	.22	21.42	20.00	16.07	19.65
White (spray enriched)	3.20	.80	75.00	.32	.25	21.90	19.20	15.05	21.61
Malekized (parboiled)	2.01	1.70	15.42	.40	.34	15.00	40.20	35.00	13.00
Converted (parboiled)	3.02	2.82	6.62	.41	.36	12.19	49.00	44.00	10.20
Earle (undermilled)	2.94	2.75	6.46	.38	.34	10.52	50.00	42.00	16.00

TABLE 5

EFFECT OF COOKING IN EXCESS WATER ON LOSS OF VITAMINS

Type of rice	Method of cooking	Cooking time minutes	Thiamine Before µg/g	Thiamine After µg/g	Thiamine Loss Percent	Riboflavin Before µg/g	Riboflavin After µg/g	Riboflavin Loss Percent	Niacin Before µg/g	Niacin After µg/g	Niacin Percent Loss
Brown	double boiler [a]	50	4.40	4.00	9.00	.81	.75	6.17	54.00	52.00	4.00
	open vessel [b]	40	4.40	2.98	32.20	.81	.60	26.00	54.00	35.70	31.00
White	double boiler [a]	30	.65	.64	1.34	.27	.25	7.40	20.57	19.86	3.45
	open vessel [b]	20	.65	.30	54.00	.27	.13	48.15	20.57	20.00	41.00
Malekized	double boiler	27	2.01	1.88	6.46	.40	.37	7.50	40.20	39.30	2.23
	open vessel	22	2.01	.86	57.21	.40	.20	50.00	40.20	25.00	37.80
Earle	double boiler	45	2.94	2.90	1.36	.38	.36	5.20	50.00	48.50	3.00
	open vessel	30	2.94	1.70	42.17	.38	.18	36.00	50.00	31.15	37.70
Converted	double boiler	30	3.02	2.86	5.30	.41	.30	7.30	49.00	48.50	2.04
	open vessel	22	3.02	1.70	43.71	.41	.29	29.44	49.00	30.60	37.55
Brand (enriched)	double boiler	30	3.00	2.90	3.33	.25	.23	8.00	20.00	19.20	4.00
	open vessel	20	3.00	1.63	45.66	.25	.16	36.00	20.00	12.00	40.00
White (enriched)	double boiler	30	1.40	1.36	2.85	.29	.27	6.80	19.50	18.62	4.51
	open vessel	20	1.40	.65	53.57	.29	.18	37.93	19.50	11.00	41.00
White (enriched)	double boiler	30	3.20	3.05	4.70	.32	.30	6.20	19.20	18.50	3.04
	open vessel	20	3.20	1.59	50.00	.32	.20	37.50	19.20	10.00	47.90
Brand (enriched)	according to [c] directions on container	20	3.00	1.09	63.70	.25	.17	32.00	19.20	10.00	47.00
Converted	according to [d]	20	3.02	2.44	19.21	.41	.30	26.83	49.00	38.18	25.12

---

[a] One cup of rice and three half-cups of boiling water are placed in the top of a double boiler cooker. All the water is absorbed in the cooked rice, which is not rinsed afterwards.

[b] One half-cup of rice is placed in an open vessel, covered with eight cups of boiling water, cooked, placed in a colander and drained.

[c] One cupful of ——— "enriched" rice is placed in an open vessel with ten cupfuls of water (boiling), cooked, placed in a colander and drained.

[d] One cup of rice is cooked in one quart of boiling water, drained in a colander and quickly rinsed in cold running water.

brown, white, and processed rices, including white rice "enriched" by spraying with a solution of vitamins. For convenience and in accordance with widespread practice in the United States, two contrasting methods were chosen. A double boiler was used for cooking the rice in a small volume of water, as this makes it easy to avoid burning the rice at the bottom of the vessel. An open single vessel was used for cooking the rice in a large volume of water. One cup of rice and one and one-half cups of boiling water were placed in the top of the double boiler and cooked until all the water was absorbed in the cooked rice, which was not rinsed after cooking. In open-vessel cooking, one-half cup of rice was added to eight cups of boiling water, the rice was cooked, transferred to a colander and drained.

Double boiler cooking was used as a demonstration of a good method of cooking and the open vessel type was employed as an example of a poor method of cooking. The results of this experiment are given in Table 5, which shows that all types of rice lose an average of 4.29 percent of thiamine in the double boiler method, compared to 46.85 percent in the open vessel type. The loss is more than eleven times as great in the latter case. Similar observations were made for riboflavin and niacin. The average losses in riboflavin and niacin using the double boiler type of cooking were 6.74 percent and 3.35 percent respectively, versus 43.00 percent for riboflavin and 44.80 percent for niacin when the open vessel type of cooking was used. The average percentage losses of thiamine, riboflavin, and niacin in open vessel cooking in the group of processed, brown, and undermilled rice were 38.9, 33.6, 33.8, respectively, compared to 53.4 percent, 39.4 percent and 43.4 percent in milled white rice. This would indicate that water-soluble vitamins, though somewhat better retained in parboiled, brown, and undermilled rice than in milled white rice, are extensively lost when rice is carelessly cooked. Practically all the vitamins present in rice before cooking can be saved and benefit the consumer when a good method of cooking is employed, using the minimum amount of cooking water and doing no rinsing after cooking. However, much of the vitamin content can be lost in careless handling of the rice in the kitchen.

Poor directions for cooking often appear on packaged rice sold in the United States. An artificially but superficially enriched rice was found to bear the following instructions: "One cup of rice is placed in an open vessel with ten cupsful of water (boiling), cooked, placed in a colander and drained." Cooking this rice by these directions resulted in the loss of over 60 percent of the thiamine and a large fraction of the riboflavin and niacin. By careful cooking, these losses were reduced to 3.3 percent thiamine, 8.0 percent riboflavin, and 4.0 percent niacin.

Similarly, a brand of converted rice sold in package form bears the following: "Pour slowly 1 cup of rice into 1 quart of fast boiling water, adding 1 teaspoon salt. Cook 20 minutes or longer. Drain in colander, rinse quickly with cold running water and each grain stands apart." Table 5 indicates the extent of losses which such a method involves.

THE NUTRITIVE QUALITIES OF RICE

In view of the fact that rice and wheat are the staple cereals of large segments of the population of the globe, it is of interest to compare their nutritional qualities. One may compare the two grains in their brown whole-grain form. This is of considerable academic interest from the standpoint of the inherent properties of the two cereals. However, from a practical standpoint, a comparison of the two in their white refined form is more important as this white form constitutes a large part of the world consumption of each. In the following paragraphs, some comparisons appear both on the whole grain and on the refined grain basis and an intercurrent discussion is included of corn (maize), the world's third great cereal.

The nutritive importance of the cereals lies primarily in their high fuel value and in their low cost, but whenever they constitute a large fraction of the caloric intake, consideration must be given to their special nutritive qualities. The nutritive qualities of rice as compared with those of wheat

TABLE 6

AVERAGE COMPOSITION OF CORN, RICE, AND WHEAT

	Corn[b]	Rice[b]		Wheat[b]	
	Whole	Brown	White milled	Whole[a]	White Flour
100 calorie portions (in grams)	27.0	28.0	29.0	28.0	28.0
Protein (percent)	10.0[a]	8.9	7.6	11.1[a]	9.3
Fat (percent)	4.3[a]	2.0	0.3	1.7[a]	1.0
Carbohydrate (percent)	73.4[a]	77.2	79.4	75.5[a]	77.2
Fuel value per hundred grams (in calories)	372.0[a]	356.0	351.0	362.0[a]	355.0
Ash (percent)	1.50	1.90[d]	0.4	1.8	0.5
Fiber (percent)	2.3	1.0	0.2	2.4	0.4
Minerals (percent)					
Calcium	0.015	0.084	0.019	0.030	0.020
Magnesium	0.160	0.119[a]	0.028[a]	0.170	......
Potassium	0.400	0.342[a]	0.079[a]	0.480	......
Sodium	0.050	0.078[a]	0.028[a]	0.100	......
Phosphorus	0.430	0.290	0.096	0.400	0.002
Chlorine	0.062	0.023[a]	0.006[a]	0.090	......
Sulfur	0.14	......	......	0.180	......
Iron	0.003	0.0020	0.0009	0.004[a]	0.00084
Manganese (parts per million)	6.83[a]	......	10.14[a]	45.91[a]	......
Copper (parts per million)	4.49[a]	3.60	1.90	7.87[a]	1.70
Vitamins (parts per million)					
Ascorbic acid	0[a]	0[a]	0[a]	0[a]	......
Thiamine	4.4[f]	3–5[d]	0.6–1.0[d]	3.2–7.7	0.87
Riboflavin	1.3–1.5	.8–1.0[d]	0.28[d]	1–1.2	0.40
Nicotinic acid	21[c] (yellow)	55[d]	15–20[d]	53	10.00
Pantothenic acid	8[c] (yellow)	17	6.4	13.4	5.70
Pyridoxine	.....	10.3	4.5	4.6	2.20
Choline chloride	370[c] (yellow)	......	880[c]	920[c]	520[c]
	0[a] (white	.5–1.0[a]	0[c]	0.2–0.25[a]	
Vitamin A (International units per gram)	7–7.5[a] (yellow)				
Tocopherol	25.0[c] (white) 31.0[c] (yellow)			9.10	0.30

---

[a] Sherman, H. C. Chemistry of Food and Nutrition. The Macmillan Company, New York, 1941.

[b] Jacobs, M. B. The chemistry and technology of food and food products. Interscience Publishers, Inc., New York, N. Y., 1944. Values are from this source when not otherwise indicated.

[c] Adams, G. and Smith, S. L. Experiment Station Research on the Vitamin Content and the Preservation of Foods. U. S. Dept. of Agr. Miscellaneous Publ. No. 536, 1944.

[d] Data from own analysis (M. C. Kik).

[e] Shollenberger, T. S. and Jaeger, Carol M. Corn. Its by-products and uses. Commodity Development Division, Northern Regional Research Laboratory, Peoria, Ill., 1943.

[f] Connor and Straub. Cereal Chem. 18: 671 (1941). This value is for white corn which showed a range from 2.54 to 7.4.

and corn can be estimated from a knowledge of their content of the major nutrients: proteins, fats, carbohydrates, mineral constituents, and vitamins, corrected more or less for failure of the body to assimilate these constituents completely. The average chemical composition of corn, rice, and wheat in both whole grain and refined form is presented in Table 6.

We shall now compare briefly the composition of the three grains in the whole grain form and then discuss more fully the comparison of their white form, with special emphasis on rice and wheat.

In comparison with corn and rice, wheat is the best source of protein and also has a higher content of thiamine, riboflavin, and niacin. Corn is deficient in niacin compared to the other grains and accordingly is often a contributing factor in pellagra.[14] In spite of a relatively low niacin content in milled rice, there has been little association of pellagra with polished rice diets. There is little to suggest historically a specific association of ariboflavinosis with any one of these grains. It is liable to occur when any of them predominates in the dietary to high degree. All the cereals are low or lacking in vitamin A (except yellow corn), vitamin C, and vitamin D. They are fair sources of iron, the availability of which is 50 percent in wheat. Wheat germ oil is the richest source of vitamin E and rice oil contains some vitamin E and vitamin A.

TABLE 7

AMINO ACID CONTENT OF RICE, CORN, WHEAT, AND CASEIN

Material	Cystine percent	Tryptophane percent	Lysine percent	Arginine percent	Histidine percent
Brown rice	0.090	0.074	0.260	0.254	0.064
Polished rice	0.073	0.066	0.280	0.251	0.059
White corn	0.096	0.047	0.107	0.212	0.089
Whole wheat	0.157	0.080	0.872	0.356	0.080
Casein	0.300	0.950	7.120	3.540	2.340

The quality of the proteins of these cereals in whole grain form is about the same. At approximately the same level of protein intake (5 percent) the biological value of the proteins of these cereals is 72 for corn and 73 for rice, compared with 67 for wheat at an 8 percent level. A value for wheat at a 5 percent level is unavailable but a somewhat higher value than 67 would be expected at this lower level of intake. Supplementation of white wheat flour with milk, eggs, or meat and of rice[15] with milk powder, leads to better utilization of total protein. In addition, it has been reported that calcium increases the biological value of rice proteins. The content of tryptophane, arginine, and histidine in rice is comparable to the content of those essential amino acids in wheat and corn; the lysine content is low, even lower than that of wheat. This is probably the most serious amino acid defect of rice. Wheat protein is deficient in lysine; corn protein, in both lysine and tryptophane. Brown and polished rice are low in cystine compared to casein and to wheat.

---

[14] W. A. Krehl, L. J. Teply and C. A. Elvehjem. Corn as an etiological factor in the production of a nicotine acid delinquency in the rat. Science 101: 283 (1945).

[15] Arkansas Agr. Exp. Sta. Bulletin, December 1942, No. 428, page 21.

Table 7 shows the available data on the contents of these essential amino acids in the three cereals.[16]

A diet in which any cereal predominates requires supplementation with a good selection of other foods. This is true of rice. In addition to cereals, a diet should include milk, vegetables, fruit, fish, and meat. These foods are not only richer than cereals in certain minerals and vitamins, but contain them in proportions more suited to the body needs.

All three cereals are low in calcium and addition of calcium to cereal diets has a beneficial effect.[12] The ratio of calcium to phosphorus in rice is approximately 1:10, which is unfavorable for maximum availability and utilization in nutrition. The optimum ratio is 1 : 2 or 1 : 1. The phosphorus content of rice is satisfactory in point of quantity; however, it occurs in rice, as in other cereals, mostly as phytin, an organic combination, and in this form it is not easily absorbed by the animal organism. Supplements of calcium in the form of milk and vegetables favorably influence assimilation of the phosphorus compounds in rice. Vegetables have an acid-base ratio inverse of that in rice and other grains; they are also a good source of phytase, an enzyme which renders available the phytin of the grains.

Nutritional Status in Rice Areas of Asia

The best insight into the shortcomings of rice as a food grain is to be found in practical experience in Asia, in view of its extensive use in that country. The most satisfactory analysis of this question is presented in a memoir by Aykroyd et al., "The Rice Problem in India." [12] This takes into account the known facts of modern nutritional principles. The study is, however, confined largely to India, where conditions are somewhat peculiar in that parboiled rice is preferred in the greater part of the country. The use of raw rice, according to Aykroyd et al., is limited to the coastal area on the Bay of Bengal extending from a point about 50 miles north of the city of Madras northward for about 600 miles in a band averaging 100 miles in width. This area of the Northern Circars has a population of about 14 million, less than a tenth of the total rice-eating population of India, which tends to make the Indians as a whole rather atypical of rice-eating populations. Parboiled rice is superior to machine-milled white rice not only in its content of the B vitamins, but also in retention of the superior proteins of the bran and germ. However, these differences, aside from the B vitamins, are not large compared with the variations from country to country in the character and quantity of components of the dietary other than rice. Accordingly, one will presumably form a reasonably correct opinion of rice as a staple cereal from this study of India.

Nutritional edema has been observed in China [17] among soldiers during the civil wars. Its occurrence has been frequent during famines in India, China, Mexico, and Russia and it was well described during World War I. Even as late as 1914, its specific cause was still unknown. Lack of protein in the diet, a condition which one would suppose liable to occur in the Orient where such an abundance of rice is eaten, causes a disease known as nutritional edema, hunger edema, war edema, or prison dropsy. It is most conspicuous in war time or during famines. The lack of protein leads to depletion of albumin in the blood serum. A normal concentration of the albumin is needed for the efficient maintenance of the blood volume. If, however, the concentration of the albumin falls, large amounts of fluid escape from the blood into the body tissues and swell them to a puffy condition especially noticeable in the extremities. Tremendous intakes of protein are frequently required for the correction of these conditions. Milk, meat, eggs, and soybeans, or sometimes an injection of an amino acid mixture, are given. Either course will correct the condition.[18]

---

[16] Arkansas Agr. Exp. Sta. Bulletin, 1942, No. 416, page 21.

[12] *Supra.*

[17] *J. Heng Liu*, Dietary Habits of the Chinese. From "A Brief Review of Food and Nutrition in Five Countries". War Food Administration, U. S. Dept. of Agriculture. 1944.

Aykroyd[12] says that in India a deficiency of protein in typical rice diets is of minor importance. Calcium deficiency is one of the major faults in the Indian rice eater's diet. Beriberi, night blindness, and keratomalacia (softening of tissues in the cornea) due to vitamin A deficiency, and stomatitis (inflammation of the mouth), in which deficiency of nicotinic acid plays a role, are very common. Anemias of varying kinds, probably due to the low iron content when extra demands are imposed by such conditions as malaria and hookworm, appear among rice eaters. Riboflavin deficiency, due to the low milk consumption, is common.

POLISHED RICE AND BERIBERI

Beriberi is caused by a pronounced deficiency of the antineuritic vitamin, vitamin B_1 or thiamine. Up to 80 percent of this vitamin is removed during the process of milling brown rice to white polished rice and the disease is found principally in those regions where people live on diets containing large amounts of polished rice. Beriberi occurs abundantly in south China, southeastern India, Japan, Netherlands India, Philippines, Burma, Siam, Indo-China, and scatteringly elsewhere throughout the world. In several Oriental cities, beriberi is among the foremost causes of death. Women of childbearing age are generally affected by it in mild chronic form. Infantile beriberi in breast-fed babies is extremely prevalent. Acute beriberi often breaks out in large labor gangs. The extent of partial incapacitation of all classes by the disease is incalculable because of lack of adequate clinical surveys, but it must be very large.

The substitution of parboiled rice for polished rice is an effective prophylactic against the forthright disease as was demonstrated by Fraser and Stanton in 1909 in the Malay States. Another very striking illustration of the relation of beriberi to white polished rice was provided by the Philippine Scouts. Prior to 1910, the ration of these troops consisted essentially of beef, white flour, potatoes or onions, and polished rice. From 100 to 600 of a total of 5000 scouts developed symptoms of beriberi annually. The number of cases was decreased to 50 within a year and later fell to nearly zero when the polished rice was replaced with undermilled rice, beans, and sweet potatoes. These and other evidences of the causal relation between white rice consumption and beriberi are critically reviewed by Vedder.[19] While his book reflects the then immature state of knowledge of deficiency disease, his principal thesis is well supported and has now been universally accepted.

---

[18] Elman, R. Protein deficiency in surgical patients and its correction. Journal of the Am. Diet. Assoc. 18: 141 (1942).

TABLE 8

RECENT PREVALENCE OF BERIBERI IN THE ORIENT

Year	Madras Presidency[a]				Japan[b]		Philippines[c]	
	Northern Circars		Remainder		Pop. 70 million Deaths		Christian pop. 14 million Deaths	
	Pop. 13.9 million		Pop. 32.9 million					
	Cases	Deaths	Cases	Deaths	Infant	Adult	Infant	Adult
1924	......	..	...	..	......	......	13,193	5,820
1925	......	..	...	..	11,866	15,130	13,493	5,048
1926	......	..	...	..	8,720	9,613	14,027	5,182
1927	......	..	...	..	7,453	6,456	12,575	4,500
1928	......	..	...	..	6,976	5,133	12,291	4,492
1929	......	..	...	..	9,920	9,116	15,141	5,084
1930	......	..	...	..	8,649	6,807	16,485	5,089
1931	......	..	...	..	8,277	7,142	15,018	4,520
1932	16,091	93	665	3	9,770	7,997	13,302	3,871
1933	20,513	55	822	2	7,162	4,643	14,720	3,962
1934	21,849	42	711	5	8,074	5,754	17,054	4,365
1935	34,639	89	382	8	6,720	4,774	14,299	4,315
1936	20,814	94	452	7	......	......	11,316	3,506
1937	27,488	65	748	5	6,791	4,306	13,004	3,793
1938	32,717	64	649	4	......	......	13,217	3,833

[a] Aykroyd, W. R., Krishnan, B. G., Passmore, R., and Sundarajan, A. R., The rice problem in India. Indian Medical Research Memoir 32, 1940, p. 4.

[b] Japan. Annual Health Reports of the Sanitary Bureau.

[c] Philippine Islands. Annual Reports of the Bureau of Health.

Beriberi is still an important disease in the Orient, as shown by the statistics of Table 8. Beriberi is of less importance outside of the Orient. However, it occurs sporadically in many places, notably where a refined starchy diet is used. Local epidemics have occurred in Africa and South America. Sailors on sailing vessels, supplied with a diet composed largely of hard tack, used to be very subject to so-called "ship's beriberi." Beriberi was also often reported in Newfoundland[20] where white bread was a primary staple and other foods were scanty during hard times.

Many cases have been reported in various parts of the United States under varied circumstances. The occurrence of beriberi among farmers in Louisiana has been described as specifically associated with rice. Though farmers are rice growers, they sell their rice crop, and polished rice is bought as their staple cereal. It is said that in autumn their diet consists mainly of polished rice and bacon grease (riz et sauce) and they develop symptoms of the disease. In winter, they eat potatoes, bread, and meat from home-slaughtered animals, and no new cases of the deficiency disease occur.[21]

---

[19] Vedder, E. B. Beriberi. William Wood, New York, 1913.

[20] Aykroyd, W. A. Beriberi and other food deficiency diseases in Newfoundland and Labrador. Jour. Hyg. 30: 357 (1930).

PROPOSED CORRECTIVE MEASURES AGAINST BERIBERI[12]

The investigations of Fraser and Stanton first demonstrated that beriberi resulting from the consumption of highly milled rice can be prevented by eating undermilled rice. Measures designed to encourage the use of such rice have been repeatedly proposed at various congresses of the Far Eastern Association of Tropical Medicine. The idea of legislative encouragement of undermilling was tentatively advanced at its first meeting in Manila in 1910. In 1921, the fourth congress was held in Batavia and an international commission was appointed to study the control of beriberi by the use of undermilled rice. The governments concerned were urged at that time to consider discouragement of the use of rice with less than 0.4 percent of phosphoric acid, for, according to Fraser and Stanton, approximately this percentage of phosphoric acid is present in rice which is sufficiently undermilled to be prophylactic for beriberi.

At the next congress held in Singapore in 1923, the recommendations of this commission were received, but for several reasons the government representatives declared that international legislative action designed to prohibit the use of highly milled rice was impracticable. Doubts were still expressed about the etiology of beriberi; the phosphoric acid test was shown to be more or less unreliable; undermilled rice was unpopular because of its unpleasant taste and its deterioration in storage and the trade was still inclined to resist any change. It was, accordingly, recommended that more research work be done on standardization of rice and on the effects of transport and storage.

In 1937, the League of Nations' Inter-Governmental Conference of Far Eastern Countries on Rural Hygiene met in Java. It was agreed that there was still a growing tendency for less use of undermilled, or home-pounded, rice, and more use of highly milled rice. This was condemned from the standpoint of nutrition but it was felt that economic and other factors should be studied further before an effective policy could be formulated. The Conference recommended the use of undermilled rice in government institutions and popularization of its use elsewhere by education and propaganda. Attention was called to the desirability of checking the spread of mechanical rice mills in rural areas and promoting the availability of home-pounded rice to consumers.

In November 1937, the Nutrition Advisory Committee of the Indian Research Fund Association met and recommended that investigations be undertaken in India along the lines indicated by the Java meeting. The subsequent studies made in India are summarized in the memoir by Aykroyd et al. previously mentioned. The principal findings with respect to their bearing on the general problem of beriberi are outlined below. Forthright beriberi in India is limited to the Northern Circars, an area of Madras Presidency comprising the coastal region extending from a point 50 miles north of Madras to the borders of Orissa. This is the area in which rice is milled in the raw state, that is without parboiling. Elsewhere throughout the southern and eastern parts of India rice parboiled before milling is used. Retention of vitamin B_1 is far greater in parboiled rice (see page 58), and only very mild forms of beriberi are present where it is used. The practice of preparing rice for consumption by home pounding is still largely followed in many parts of India. In this type of milling, a substantial fraction of the pericarp is retained whether the rice has been parboiled or not. This is especially important in the case of raw rice. The custom of using machine-milled rice, both raw and parboiled, is spreading in rural as well as urban areas; in 1939 about 70 percent of the rice-eating population of Madras Presidency consumed such rice. The reasons for the abandonment of home pounding are many: small rice mills are increasing as cheap electricity becomes available; better roads and transportation facilities enable the paddy grower to bring his rice to a mill; the malnourished and exhausted village women, who do the pounding, seek to avoid that hard labor; undermilled or home-pounded rice is unavailable in cities. There the industrial town laborer has no facilities for pounding rice and machine-milled rice is bought almost exclusively. Even small rice growers sell their products and buy machine-milled rice. Often there is lack of storage space for paddy and lack of equipment for pounding. Many villagers have sold their pounding equipment after the arrival of small mills. Furthermore, home-pounded rice is more expensive and cannot meet the competition of the cheaper kinds of rice which are eaten in highly milled form by the poorer classes.

---

[21] Scott, L. C., and Herrmann, G. R. Beriberi . . . in Louisiana. J. Am. Med. Assoc. 90: 2083 (1928).

From the present authors' study of the subject it seems doubtful that the degree of undermilling can be adequately controlled unless milling is eliminated entirely and provision is made for expeditious transit of the whole brown rice from the rice-shelling mill to the consumer to avoid spoilage in storage. This is said to have been done in recent years with large amounts of rice produced in Java, but we cannot vouch for the authenticity of the statement.

While the thought of public health authorities in the Orient has centered largely about the encouragement of undermilling, other expedients have at least been mentioned. Van Veen[22] considered the incorporation of synthetic thiamine in the salt supply but dismissed it on the ground of cost and because of deterioration of thiamine in admixture with salt during long storage. The cost factor is much less serious than formerly, since 1 milligram of thiamine per capita daily can now be supplied at a cost of 5.8 cents per annum at the price in the United States. The problem of stability is not fully resolved. According to a progress report furnished by Dr. R. T. Major, thiamine present in salt in a concentration of 1 part in 5000 lost activity during storage for 4 months to the extent of 2.7 percent to 29 percent, depending chiefly on the purity of the salt and secondarily on temperature of storage. The higher loss was encountered at a storage temperature of 40°C, when thiamine was mixed with a sea salt of Indian origin supplied by Dr. W. R. Aykroyd. Further experimental work is in progress. This has already indicated that this loss can be reduced to one-fifth or one-tenth of the higher figure by relatively simple compounding expedients. A fuller report will be awaited with interest when the work is completed.

---

[22] Van Veen, A. G., Technical Commission on Nutrition, League of Nations. C. H. Com. Exp. Alim. 66 (1939).

Another expedient that has been advocated less intensively than undermilling is the more widespread use of parboiled rice. Parboiled rice is customarily used in the larger part of India and in these areas the product is preferred to white rice by the people accustomed to it. The process consists in soaking the rough rice or paddy in warm or hot water for some hours or days, after which the water is drained off and the rice is dried and milled in the usual way. Often steaming follows or replaces steeping. More detailed discussion of this topic is given on page 58. This practice has spread to points in Malaya where Indian immigrants are numerous and is followed in Ceylon and in British Guiana. It is practiced in Burma on rice for export to India and is under trial in China at Chungking, but the product is not accepted there with favor. There are two large parboiling plants near Buitenzorg, Java.

COMMERCIAL MILLING OF RICE

The Milling Process

In the Orient a vast quantity of rice is milled by manual labor, utilizing primitive devices. The most important of these is the wooden mortar and pestle, the latter being lifted by hand or with the foot by means of a lever. The mortar and pestle is even harnessed to mechanical power generated by steam or hydrostatically. However, in the larger mills machinery has been introduced from the West. The milling process used in the United States is little more refined than that of the larger commercial mills in the Orient and is essentially the same in principle. In the following discussion of the milling process proper, it may be well to have in mind the structure of the rice grain. This is illustrated in Figure 1.

The rice is first cleaned mechanically. Sifting removes sticks and stones, aspiration with an air stream takes out dust beards, stems, and light blighted grains. The resulting cleaned paddy is now subjected to removal of the hulls by machines called shellers. These consist of a stationary plate and an opposed plate rotating at about 190 rpm, both plates being mounted in a horizontal plane. The paddy passes through a central hole in the upper plate which in some machines is stationary; in others it is the rotating member. The plates are usually of steel about four or five feet in diameter and are coated on their inner surfaces with a mixture of cement and coarse carborundum. Formerly these plates consisted of stones with suitably chipped inner surfaces. In either case it is necessary to renew the roughness of the surfaces periodically by rechipping with a special hand tool for the purpose.

The plates operate with their inner faces about ¼ inch apart, but this spacing is closely adjustable to the mean length of the grains to be shelled. Ad-

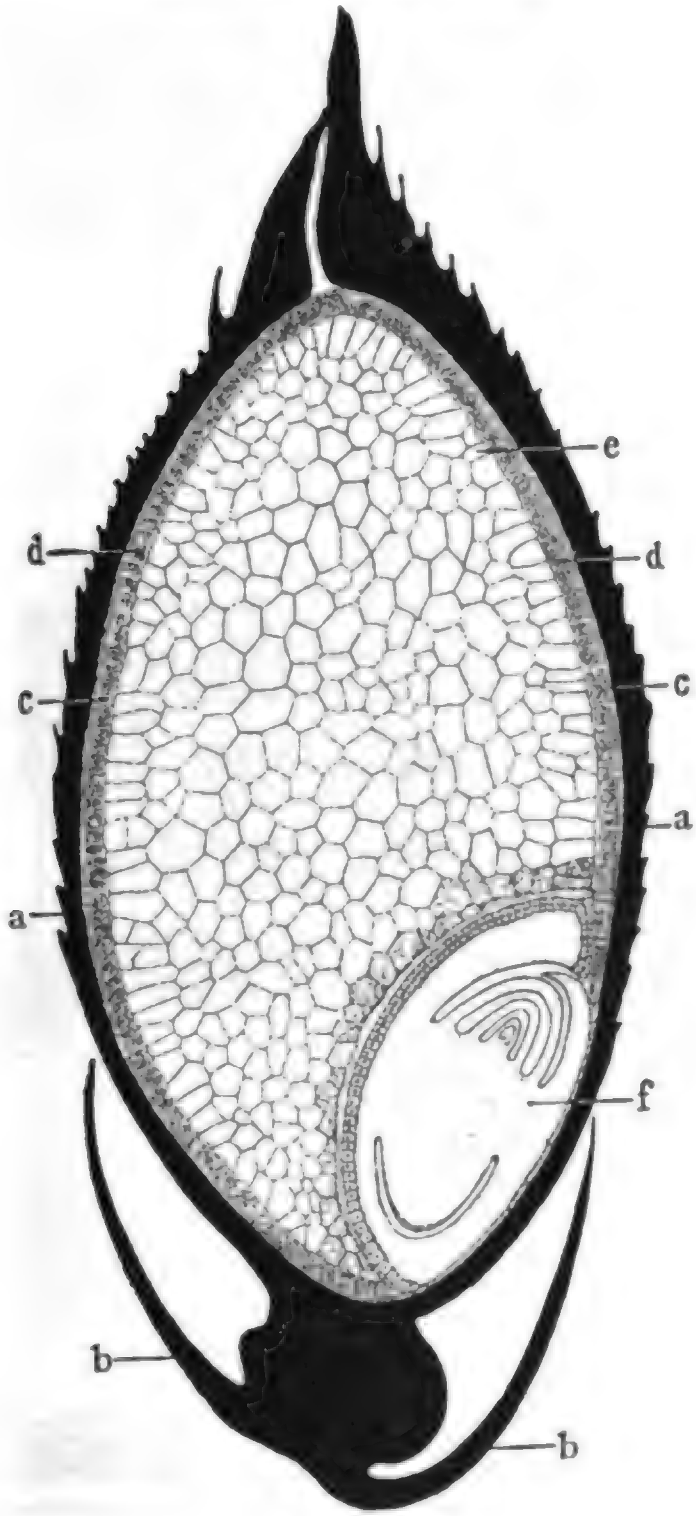


FIGURE 1

Longitudinal Section of a Rice Grain *

The hull or husk (a) consists of two ridged inner glumes called the palet and the lemma and of two empty sterile outer glumes (b).

The next layer (c) is a thin cover consisting of the remains of the ovary walls (pericarp) and of the seed coat. Then follows the aleurone layer (d) which is rich in nutrients. These two layers are removed in the milling process by the skinning machines and form the bran. The major part of the rice kernel is the endosperm and even some of this must be removed in order to get rid of all the tightly adhering coats. The embryo or germ (f) is situated at the base of the kernel and is also rich in nutrients. The side in close contact with the endosperm is called the scutellum and aids in nourishing the embryo.

* Yampolsky, Cecil. II Rice Grain and its Products. Wallerstein Laboratories Communications, Vol. VII, number 20. April 1944. Reproduced with permission of Wallerstein Laboratories, 180 Madison Avenue, New York City.

justment is made by a lever and screw supporting the driving shaft and rotating plate, often called a stone. The adjusting device is shown at the bottom of Figure 2. The action of the shelling machine is diagrammatically portrayed in Figure 3. As the paddy stream passes into the space between the plates, the grains are oriented at random. At every moment some of them are turned to a vertical or nearly vertical position, the ends of these grains are

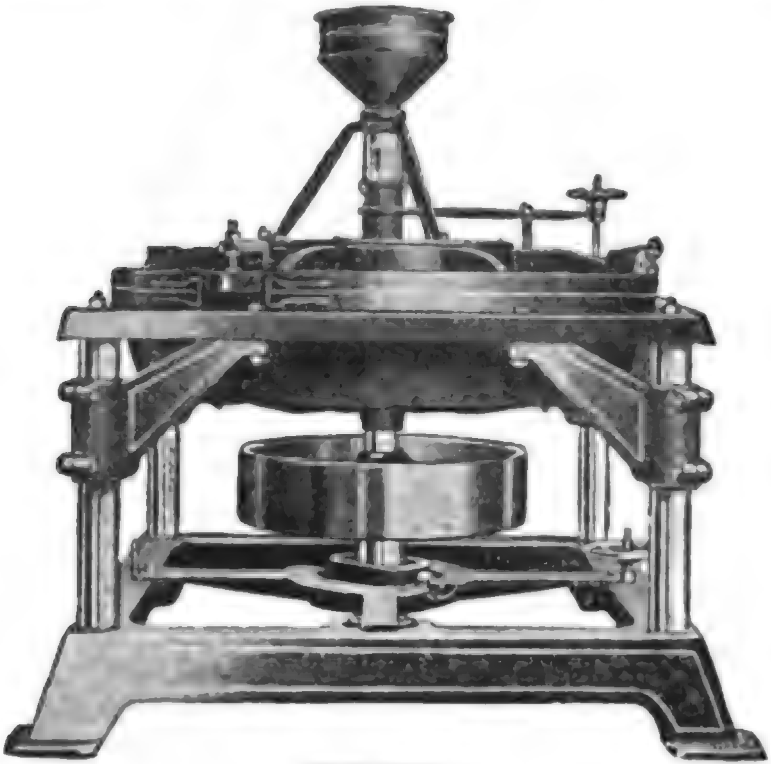


FIGURE 2

Rice Shelling Machine

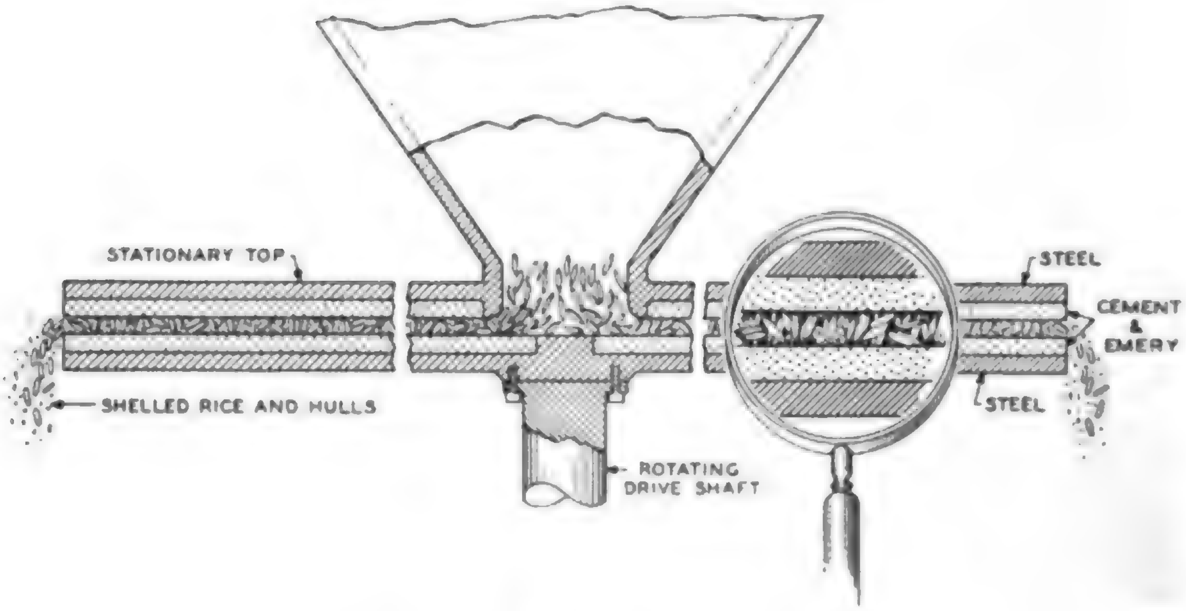


FIGURE 3

Rice Shelling Machine, Cross Section

caught by the stones and the hulls are disengaged by the impact. Others in turn are upturned and shelled. The object of the adjustment is to shell all the grains if possible without breaking any of them. Practically, the shorter grains escape being shelled. Accordingly, after passing through the sheller, the incompletely shelled grain is sorted and the unshelled fraction is passed through another shelling machine with a closer set of the plates.

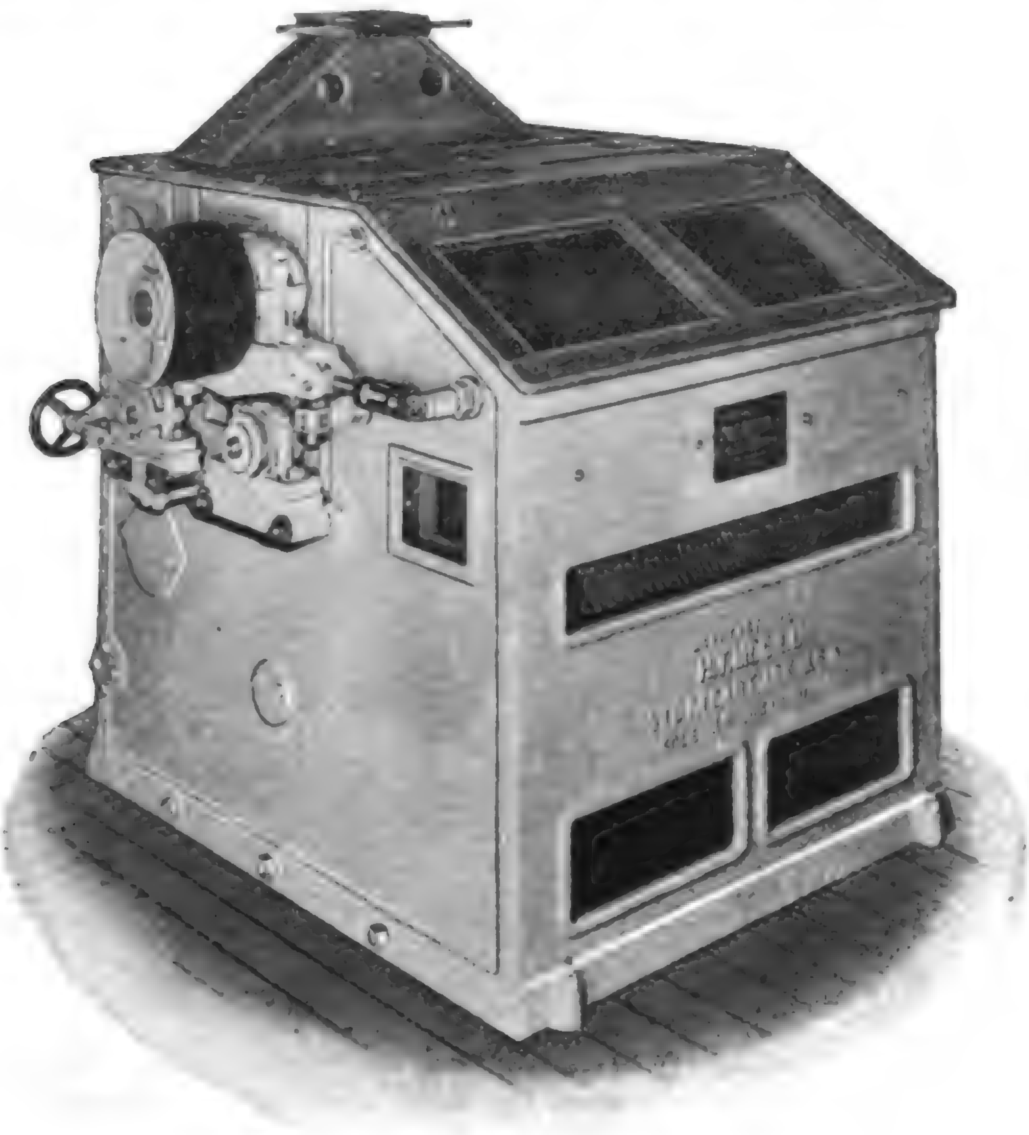


FIGURE 4

McGill Rice Sheller

Such shellers have long been in use in the rice industry and apparently relatively little effort has been devoted to their improvement. In recent years a different type of sheller is being offered and is meeting with considerable favor. A lower breakage of rice is claimed for this machine, which is illustrated in Figure 4. Its mode of operation is as follows: The knifed upper roller rotates at a peripheral speed of about 1800 to 2000 feet per minute, while a rubber belt carrying the paddy in a thin layer on its upper surface travels over a lower smooth steel roller at a speed about one third as great as the knives which strike the paddy grains on their sides and remove the hulls.

After being shelled, the hulls are removed by strong aspiration and the unhulled rice is separated from the brown hulled rice by a paddy machine. This clever machine consists essentially of a slightly tilted, smooth, steel plate with a horizontal reciprocating motion and provided with baffles which serve to distribute the rice over the entire surface and to insure ample overturning of the rice as it descends the slope. The smooth brown rice falls off the lower edge into a conveyor while the rougher and lighter unhulled grains ascend to the upper edge and fall over a slight lip into an appropriate trough.

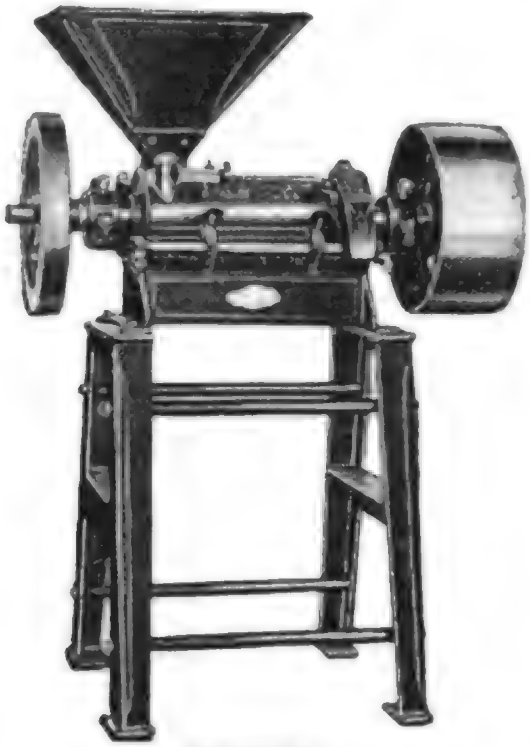


FIGURE 5

Engelberg "Huller" for Scouring Rice

The brown rice next goes to machines that are erroneously called hullers because of the fact that they were originally designed to remove the outer coverings from coffee beans. Although the term is not used in the trade, we shall refer to this operation as scouring, as this word best describes the nature of the operation. The machine (Figs. 5, 6, and 7) consists of a solid heavy fluted cylinder, E (discernible in Fig. 6 but best seen in Fig. 7), rotating at 500-600 rpm within a stationary hollow cylinder of thin sheet steel, F, uniformly perforated by closely spaced slots about 0.060 x 0.300 inches (a range of sizes is provided). The perforated cylinder is composed of upper and lower halves, the edges of which abut. The flutes on the rotating cylinder, E (Fig. 7), are so disposed as to carry the rice along the length of the cylinder and to cause it to travel around and around the inner surface of the perforated cylinder. A suitable opening, A^1, through the perforated screen admits the rice at the top at one end of the cylinder and another permits its egress at the top of the other end, I. However, in operation the entire machine is continuously packed full of grain. The outflow and accordingly the packing force is regulated by a blade, H, the full length of the barrel, which protrudes between the upper and lower halves of the perforated cylinder, F, and approaches the flutes of the cylinder, E, within it, thus retarding the movement of the grain lying next to the perforated cylinder. The action of the machine is, therefore, essentially one of scouring the moving inner mass of rice grains against those near the surface of the perforated cylinder which are retarded by the blade. By this means the bran is progressively scoured off the grains, falls through the perforated screen and is carried away by aspiration. When the blade is set closer, the rice within the machine is subjected to denser packing and the effluent rice is caused to become whiter. Great skill and constant observation on the part of the miller are necessary to secure efficient removal of the bran without excessive breakage of the grain. The grain is markedly heated by the friction. This must be kept within bounds.

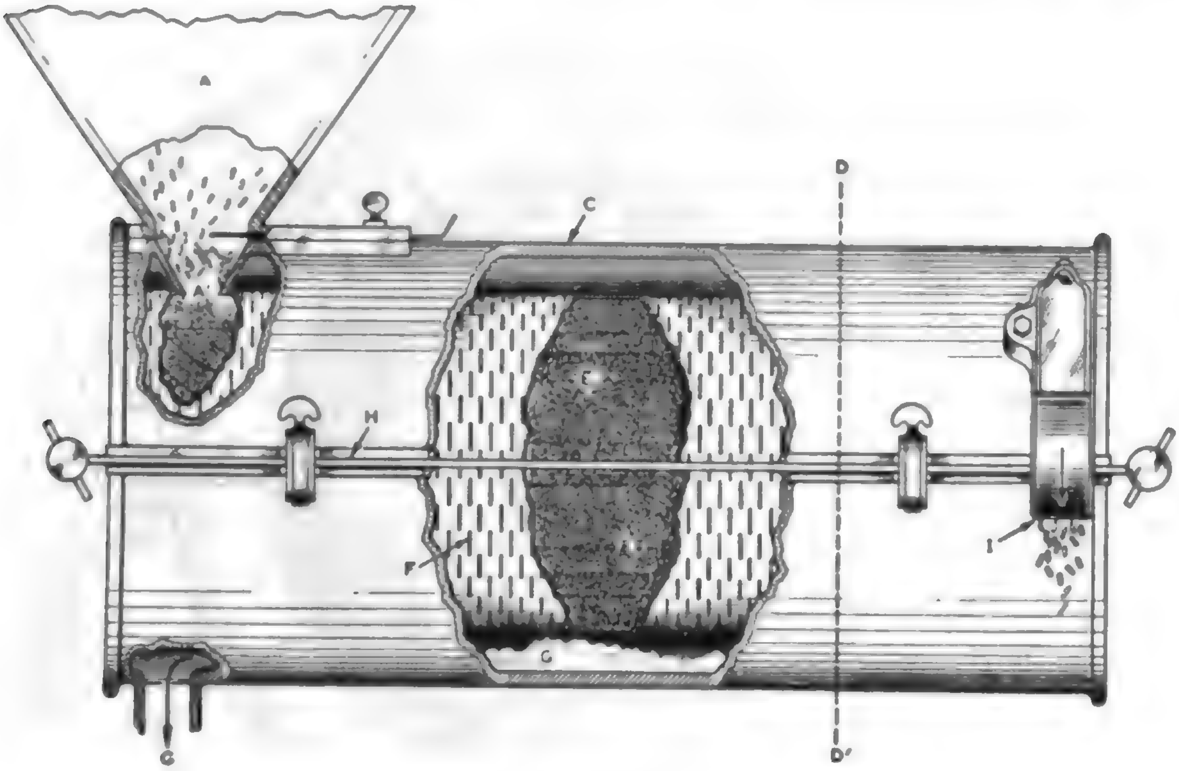


FIGURE 6

Rice Scouring Machine, Longitudinal View of Barrel

The rice enters through hopper *A* and passes through aperture A^1 in the screen *F* into the space surrounding the fluted solid cylinder *E* which acts as an impelling worm to carry the grain along the hollow cylinder *C* from left to right but within the cylindrical screen *F* through which the bran falls as it is scoured off the grains by their friction on one another and against the screen. Bran, *G*, is removed by an aspirator while the scoured rice exits at *I*. The effect of the huller blade *H* (see also figure 7) is to retard the motion of the grain lying against the screen relative to that carried along by the flutes on the screw. Scouring is therefore largely achieved by rubbing the grains against each other.

The adjustment of the blade is governed entirely by the appearance of the outgoing grain.

The bran is continuously removed by suction as it falls through the perforated cylinder. Usually the grain is passed through a succession of such scouring machines. It comes out nearly free of germ and retains only a small fraction of the bran, consisting largely of the inner layers. Some of the grains are broken at this stage, the amount depending on the variety and quality of the rice, its moisture content, and the skill of the miller.

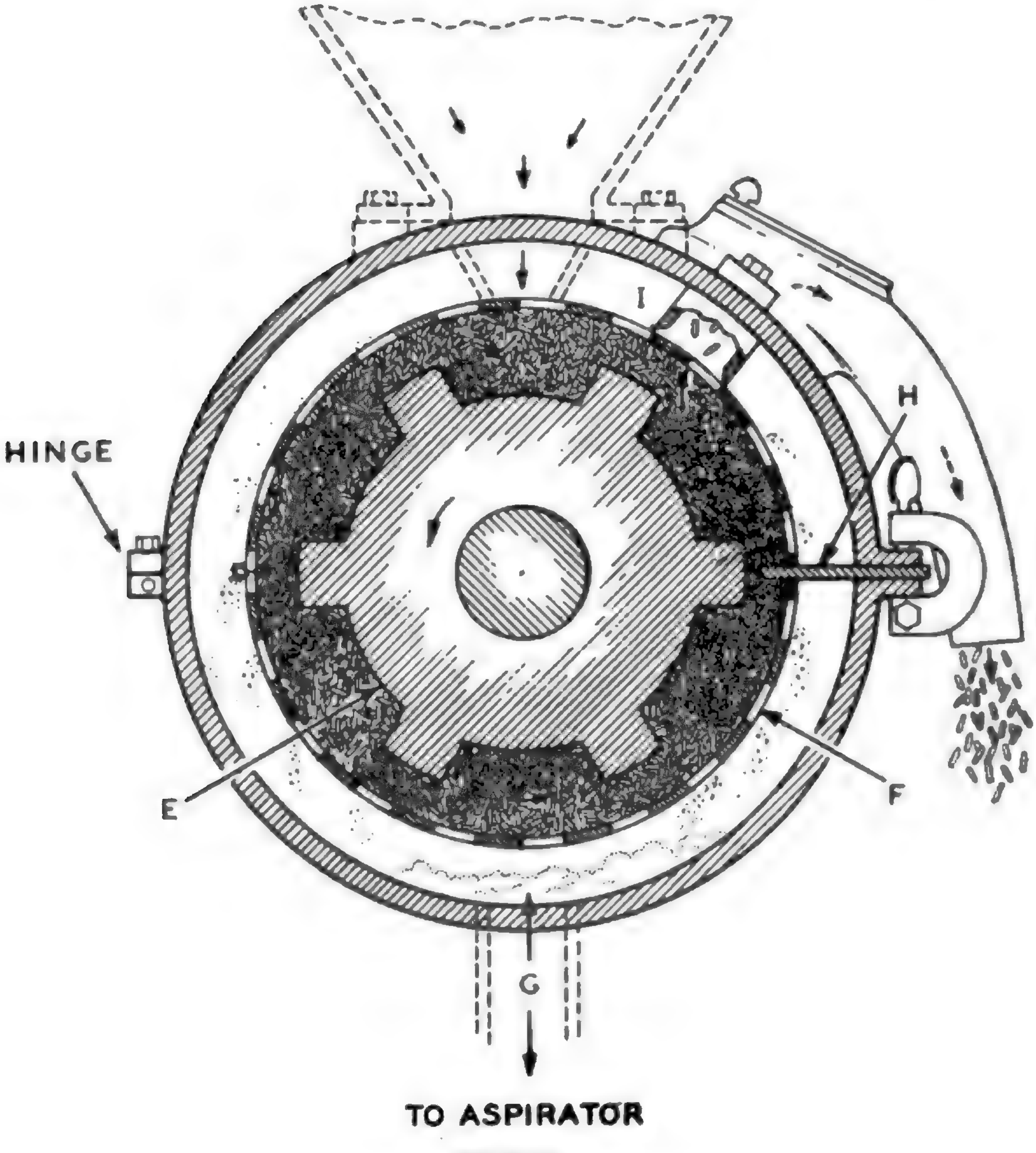


FIGURE 7

Rice Scouring Machine, End View

The lettering of Figure 7 corresponds to that of Figure 6. Alternate reference to Figure 6 and 7 will be helpful to understanding the operation of the machine.

In some mills a pearling cone is used instead of, or in addition to, a scouring machine. This is an inverted, truncated cone about 28 inches high, covered with a mixture of emery and cement, which revolves inside a steel wire screen forming another truncated cone with walls parallel to the inner cone. The whole is encased in an iron casting with openings for the grain to enter and leave as the cone spins. Rice is fed in from the top, rubbed between the cone and the sieve, and released at the bottom. By raising or lowering the revolving cone, thus adjusting the distance between the cone and screen, the amount of scouring can be regulated. To minimize the breakage, rice is usually passed through a series of these pearling cones in order that the scouring action may be gradual and gentle rather than rapid and harsh. The pearling cone is used extensively in Europe and to some extent in the Orient.

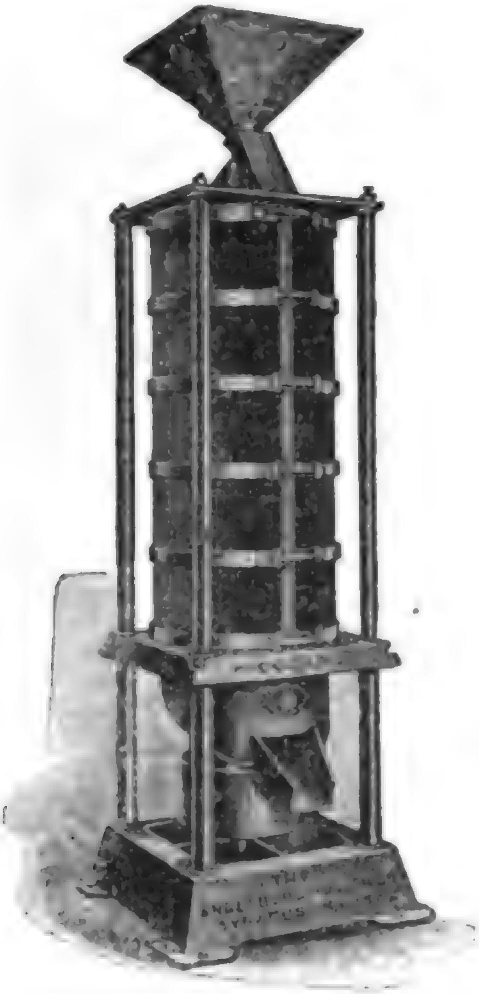


FIGURE 8

Rice Brush or Polisher

The scoured rice may pass to a polishing machine called a brush. This consists of a vertically disposed wooden cylinder about 8 feet high and 4 feet in diameter, rotating within a fairly close-fitting stationary cylindrical screen. The entire surface of the wooden cylinder is covered with strips of leather laid on the full length of the cylinder. The strips are four inches wide and each, shinglewise, overlaps its neighbor on one side and is overlapped by its neighbor on the other. Rotation is with the lap, not against it, so that the grains tend to wedge between leather and screen as they approach each successive overlap. The inner bran layers are removed, falling through the screen. They constitute the so-called rice polishings. The brush is shown in Figure 8. Its use is now often omitted.

White rice may be coated to improve its appearance by slight oiling and glazing with powdered talc, glucose, and other materials. This coating also improves its keeping quality in storage, as it offers some protection against attack by insects. It is, however, an objectionable sophistication and is now practiced less than formerly. Its use is reported to be limited to the United States, Italy, and Spain.

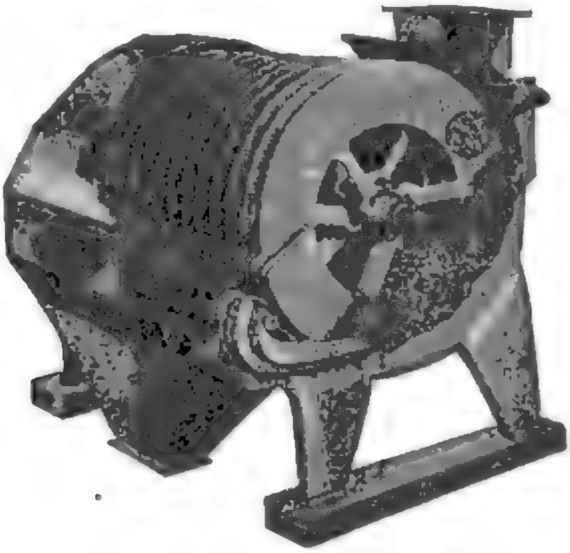


FIGURE 9

Disc Separator

The foregoing is a very brief account of a relatively complicated mechanical process that varies considerably from mill to mill. The fundamental operations, however, follow the same principles in all American mills and have endured without material change for decades. A great variety of supplementary machinery, principally for the purpose of cleaning rice, for removal of weed seeds, for sorting of broken rice grain fragments according to size, etc., are in use. Size classification is often accomplished by some form of rotating device involving surfaces with pockets of graduated size capable of elevating small particles and rejecting larger ones. The disc separator, Figure 9, is such a device of wide application.

Variation of yield of products of milling is considerable, depending on variety and quality of rice and on seasonal influences. There are about 10 varieties of rice grown in commercial quantities in the United States, usually classified into long, medium, and short grain. The 5 principal long grain varieties constitute about 25 percent of the crop, 3 medium grain varieties over 50 percent of the total, and the short grain "pearl" type of Japanese origin, grown mostly in California, represents the remainder. Breakage is rather higher in the long grain varieties.

A barrel of rough rice of 162 pounds weight represents the quantity originally considered necessary to produce 100 pounds (a pocket) of finished rice. Yields have increased so that 105 to 108 pounds of milled rice from a barrel is now common. The usual proportions of the various products for all varieties are as follows:

	Weight percent	Money Return percent	
Invisible loss and trash	2.0		
Brown Rice	79.0		
Hulls	20.0	1–2	5
Bran	8.5	2–3	
Polish	1.8	1	
Head Rice	57.8	83	95
Second Head	2.6	4	
Screenings	6.0	6	
Brewers	2.1	2	

Head rice, consisting of whole grains in milled form, represents the major value obtained. Second head, consisting of half and three quarter grains, screenings of quarter up to half grains, and brewers rice of less than quarter grain size, command successively lower prices. Bran and polish are used for stock feeds and bring in a small additional revenue. Their possibilities as human food or for other useful purposes deserve further exploration. The disposal of the large weight of hulls presents a problem. To some extent they are used as fuel, mulches, heat insulation, packing material, etc., but for the most part they are burned or scattered for disposal. They are used to a limited extent in a ground form in stock feeds, but this practice is frowned on as adulteration; the hulls injure the membranes of the alimentary tract. They contain nearly 20 percent ash, mostly silica, about 40 percent crude fibre, 30 percent carbohydrate and 2.5 percent protein. Their fuel value is actually sufficient to supply all the power required in the mill. The mills of Bangkok are so operated.

Losses of Nutrients in Milling

The process of milling of raw brown rice to white rice has been outlined in the foregoing pages. On the pages that follow we shall set forth the results of reexaminations of the problem of losses of nutrient values during milling. These have been conducted during the past four years with the aid of modern methods of vitamin analysis, including assays for thiamine, riboflavin, and niacin. The data come largely from the University of Arkansas, but in addition we have included data from modern literature when available.

In the process of milling to white polished rice, 76.3 percent of thiamine, 56.6 percent of riboflavin, and 63 percent of niacin are removed and lost for human consumption. The data of Table 9 represent the average of 44 samples of brown and 45 samples of white rice collected from numerous mills in the four rice-producing states during the years 1941, 1942, and 1943. The data on the individual samples here averaged are published in part;[23] additional previously unpublished data appear in Table 10 and Table 13. All these results are summarized in Table 9, which therefore gives a fairly representative picture of the fate of these three nutrients in the milling process.

The methods of analysis used were as follows:

Thiamine:—The samples were analyzed for thiamine by the thiochrome method, with an adaptation of the Hennessy and Cerecedo procedure.[24] The method as used in the laboratory at the Arkansas Agricultural Experiment Station is briefly as follows: Samples of 1 to 15 g. (depending on vitamin content) are suspended in 75 ml. of 0.1 N H_2SO_4, autoclaved in a pressure cooker for 20 minutes at 15 pounds pressure, cooled, adjusted to pH 4.0-4.5 with 2 N sodium acetate solution with brom cresol green as indicator. Five ml. of 10 percent takadiastase solution is added, mixed, and incubated at 50°C. for at least 1½ hours. After incubation the mixture is cooled, made up to 100 ml., and filtered. Aliquots of the clear extracts are used for the thiamine determination.

Riboflavin:—The samples were analyzed for riboflavin by a fluorometric method (Conner and Straub).[25] The method, as used in the laboratory at Arkansas, is briefly stated as follows: Samples of 5 to 10 g. (depending on vitamin content) are transferred to 200 ml. amber-colored Pyrex Erlenmeyer flasks, suspended in 75 ml. of 0.1 N H_2SO_4, autoclaved in a pressure cooker for 20 minutes at 15 pounds pressure, cooled, adjusted to pH 4.0-4.5 with 2 N sodium acetate solution with brom cresol green as an outside indicator. In order to obtain a clear filtrate, 125 mg. of takadiastase is added, mixed, and incubated at 50°C. for 1 hour. After incubation the mixture is cooled, made up to 100 ml., and filtered in the dark. Thirty-milliliter aliquots of the clear extracts are used for the riboflavin determination, with florisil used as a means of absorption and pyridine-acetic acid as an eluting agent. A blank determination containing reagents and takadiastase is run simultaneously with the samples.

Nicotinic Acid or Niacin:—Nicotinic acid was determined by the colorimetric method of Melnick (1942);[26] the analyses were made in duplicate, employing 1.0 g. samples of the main products and 250 mg. of the by-products. As a test of the suitability of the colorimetric method, the samples of whole brown rice employed in this study were submitted to another laboratory for microbiological assay. Credit is due John S. Andrews, Research Department, General Mills, Inc., Minneapolis, Minnesota, for the Microbiological Assays of these samples. The following values in micrograms per gram were obtained for samples of whole brown rice by the microbiological method: 57.1, 55.1, 53.3, 47.3, 53.5, 58.4, and 50.0; average 53.5. These values are in fairly good agreement with those obtained by the colorimetric method on the same samples, namely, 57.4, 56.4, 51.2, 52.8, 49.2, 64.7, 55.1 respectively; average 55.2. For these assays the method described by Andrews, Boyd, and Gortner[27] was used.

---

[23] Kik, M. C. Thiamin in products of commercial rice milling. Cereal Chemistry 20: 103 (1943).

Kik, M. C., and Van Landingham, F. B. Riboflavin in products of commercial rice milling and thiamine and riboflavin in rice varieties. Cereal Chemistry 20: 563 (1943)

Kik, M. C., and Van Landingham, F. B. Niacin in products of commercial rice milling and in rice varieties. Cereal Chemistry 21: 154 (1944).

Kik, M. C. Effect of milling, processing, washing, cooking, and storage on thiamine, riboflavin, and niacin of rice. Arkansas Agr. Expt. Sta. Bulletin No. 458 (1945).

[24] Hennessy, D. J., and Cerecedo, L. R. The determination of free and phosphorylated thiamine by a modified thiochrome assay. J. Am. Chem. Soc. 61: 179-183 (1939).

[25] Conner, R. T., and Straub, G. J. Combined determination of riboflavin and thiamine in food products. Ind. Eng. Chem., Anal. Ed. 13: 385-388 (1941).

[26] Melnick, D. Collaborative study of the applicability of microbiological and chemical methods to the determination of niacin (nicotinic acid) in cereal products. Cereal Chemistry 19: 553 (1942).

TABLE 9

AVERAGE THIAMINE, RIBOFLAVIN, AND NIACIN IN RICE (ROUGH, BROWN, AND WHITE) 13 Varieties, Harvests 1941, 1942, 1943

Type, and number of samples	Thiamine	Riboflavin	Niacin
Rough (34)	3.35 μg/g 1.51 mg/lb.	.73 μg/g .33 mg/lb.	53.40 μg/g 23.93 mg/lb.
Brown (44)	3.55 μg/g 1.60 mg/lb.	.60 μg/g .27 mg/lb.	53.08 μg/g 23.89 mg/lb.
White (45)	.84 μg/g .38 mg/lb.	.26 μg/g .12 mg/lb.	19.62 μg/g 8.83 mg/lb.

Table 11 gives recent data on pantothenic acid, pyridoxine, and biotin in brown and white[*] rice.

In previous studies[28] on amino acid content of rice proteins, it was found that the content of protein and of the essential amino acids, cystine, tryptophane, arginine, and histidine, is lower in white rice than in brown rice. These data are reproduced in Table 7, page 24.

Feasibility of Standardized Undermilling

The problem of improving rice nutritionally is beset with many obstacles. It is more difficult to restore vitamins and minerals to white rice than to flour because rice is rinsed before cooking. This leads to great losses when vitamin and mineral preparations are applied only to the surfaces of the grains. Restoration, or even retention, must be internal if it is to be thoroughly effective. Reduced polishing or undermilling[†] of rice, however,

---

[27] Andrews, J. S., Boyd, H. M., and Gortner, W. A. Nicotinic acid content of cereals and cereal products. Ind. Eng. Chem., Anal. Ed. 14: 663 (1942).

[*] Williams, V. R., Knox, W. C., and Fieger, E. A. A study of some of the vitamin B complex factors in rice and its milled products. Cereal Chemistry 20: 560 (1943); 21: 540 (1944).

[28] Kik, M. C. Nutritive studies of rice and its by-products. Arkansas Experiment Station, Bulletin No. 416, February 1942.

[†] We use the terms unpolished and undermilled substantially interchangeably in the present publication in the belief that any distinction between them is not significant in present American practice. Either term implies a partial retention of the bran coats, which is not assured by mere avoidance of the use of the brush or polisher. Virtually complete removal of the bran coats may occur in the scouring machine ("Huller"). The use of the term unpolished rather than undermilled was recommended by the Rice Millers' Association at a meeting in New Orleans December 5, 1943.

TABLE 10

THIAMINE, RIBOFLAVIN, AND NIACIN IN COMMERCIAL RICE (1942)

Name and location	Variety	Type	Thiamine mg per lb.	Riboflavin mg per lb.	Niacin mg per lb.
Imperial Rice Milling Co., Crowley, La.	Blue Rose	brown	1.37	0.16	25.25
		white [1]	.32	.05	9.42
Republic Rice Mill, Guedan, La.	Blue Rose	brown	1.58	.21	24.27
		white	.35	.13	8.55
		brown	1.91	.24	28.13
		white	.45	.12	7.92
International Rice Milling Co., Crowley, La.	Blue Rose	rough	1.42	.27	21.84
		brown	1.37	.20	26.51
		white	.32	.10	9.51
		second head	.28	.08	9.09
		screenings	.49	.17	10.57
		polish	10.48	1.19	117.00
		bran	11.56	1.94	119.19
Kaplan Rice Mill Kaplan, La.	Blue Rose	rough	1.80	.27	22.07
		brown	1.41	.23	25.33
		white	.27	.14	8.10
		bran	8.10	1.54	118.90
		polish	13.41	1.37	111.25
Lake Rice Mill, Lake Arthur, La.	Blue Rose	brown	1.57	.26	26.46
		white	.23	.15	8.50
Edmundson-Duhe Rice Mill, Rayne, La.	Rexoro	rough	1.35	.25	26.10
		white	.25	.11	9.32
United Rice Milling Products, New Orleans, La.	Rexoro	brown	1.35	.23	25.97
		white	.27	.10	6.75
Rickert Rice Mills, New Orleans, La.	Prolific	rough	1.53	.21	24.30
		brown	1.98	.22	23.40
		white	.47	.10	7.65
	Pearl	rough	1.73	.25	22.14
		brown	1.97	.22	26.28
		white	.39	.09	8.23
	Blue Rose	rough	1.80	.24	20.24
		brown	2.02	.23	26.82
		white	.57	.09	7.70
	Fortuna	rough	1.53	.30	37.50
		brown	1.99	.23	27.16
		white	.36	.14	8.25
	Rexoro	rough	1.46	.26	20.20
		brown	1.86	.25	26.62
		white	.36	.14	9.33
Adolphus Rice Mill, Houston, Texas	Rexoro	brown	1.09	.23	25.98
		white	.29	.14	9.62
Beaumont Rice Mills, Beaumont, Texas	Rexoro	rough	1.35	.25	23.27
		brown	1.46	.23	27.77
		white	.25	.11	8.42
		second head	.21	.08	6.79
	Blue Rose	rough	1.58	.25	30.83
		brown	1.53	.23	26.28
		white	.35	.14	8.82

---

[1] White rice is white milled, or head rice.

TABLE 10—Continued

Name and location	Variety	Type	Thiamine mg per lb.	Riboflavin mg per lb.	Niacin mg per lb.
Arkansas State Rice Milling Co., Stuttgart, Ark.	Blue Rose	brown	2.00	.39	26.15
		white	.54	.11	9.37
Arkansas State Rice Milling Co., Carlisle, Ark.	Blue Rose	brown	1.13	.18	22.28
		white	.18	.13	9.60
New Port Rice Mill, New Port, Ark.	Zenith	brown	1.85	.25	21.66
		white	.27	.11	9.27
Graham Bros. Rice Mill, Tuckerman, Ark.	Prolific	rough	1.35	.25	27.00
		brown	1.49	.22	26.07
		white	.23	.11	8.25
		second head	.23	.10	6.30
		brewers	.31	.09	11.31
		screenings	.67	.15	13.05
		bran	9.22	1.19	113.83
		polish	12.69	1.54	151.68
Rice Growers Association of California, Sacramento, Calif.	Caloro	rough	1.35	.25	21.56
		brown	1.98	.17	24.86
		white	.45	.13	7.90
		bran	10.84	1.19	132.47
		polish	10.03	.65	136.03
Woodland Rice Co., Woodland, Calif.	California Pearl	brown	1.47	.23	24.40
		white	.37	.13	10.17
Rosenberg Bros., San Francisco, Calif.	California Pearl	rough	1.35	.25	30.65
		brown	1.41	.28	27.75
		white	.41	.17	7.52
		bran	10.84	1.19	109.46
		polish	7.20	1.26	103.50

does present a possible way of retaining at least a portion of these special nutrients in the grain as consumed.[29]

A substantial fraction of the thiamine, riboflavin, niacin, and ash constituents of the bran coats of the grain are contained in undermilled or unpolished [29] rice. This is shown in Table 12;* lower values are obtained in the milled rice, compared to the unpolished rice.

Unpolished rice is at least an effective preventive of beriberi; this has been pointed out in a previous chapter. It seemed, therefore, of importance that the use of this nutritionally improved rice should be considered in those areas of the United States where rice is a staple food, unless a better approach can be devised.

There is at present a favorable attitude on the part of rice millers in the United States toward unpolished rice because yields of edible rice are larger with less milling and consumers are now less meticulous in their demands because of war shortages of supply. No new equipment or material is needed for its manufacture; it can be obtained simply by less drastic scouring in the mill, either by loosening the huller blades or by avoiding use of the pearling cone. The result is that the miller obtains a greater weight of rice that he is able to sell. It has been estimated that from eight to ten pounds more head rice is obtained from one barrel (162 pounds) of rough rice. The usual yield of highly milled head rice from a barrel of rough rice is about 87 pounds.

---

[29] Vedder, E. B., and Feliciano, R. T. An investigation to determine a satisfactory standard for beriberi-preventing rices. Trans. Far Eastern Ass'n. Trop. Med. Seventh Cong. Dec. 1927, Vol. III, p. 375.

* Credit is due Miss Kathleen Smith for valuable analytical assistance in obtaining these and other data which follow in the text.

TABLE 11

OTHER VITAMINS IN BROWN AND WHITE RICE *

	Vitamin Content, μg per Gram of Dry Weight.					
	Pantothenic Acid		Pyridoxine		Biotin	
Variety	Brown	White	Brown	White	Brown	White
Blue Rose	16.5	6.5	9.4	2.0	0.114	0.050
Early Prolific	15.9	6.5	10.3	6.2	0.126	0.043
Nira	17.3	....	10.2	....	0.124	.....
Rexoro	15.4	....	10.7	....	0.133	.....
American Pearl	14.6	....	10.4	....	0.117	.....
Fortuna	18.6	6.3	11.2	5.3	0.123	0.034
Composite average	16.4		10.3		0.121	

*All figures represent averages of a number of samples.

The Food and Nutrition Board of the National Research Council * has been concerned with the improvement of white rice from a nutritional standpoint under present conditions, and proposed for consideration the development and marketing of unpolished rice. To make this possible, both the rice industry

TABLE 12

DEPENDENCE OF VITAMIN CONTENT ON DEGREE OF MILLING

Variety	Type of Milling	Thiamine μg/g	Riboflavin μg/g	Niacin μg/g	Ash Percent
Early Prolific	unpolished	2.14	0.52	33.10	0.90
	unpolished	1.57	0.39	27.00	0.86
	milled	0.91	0.26	20.00	0.57
Lady Wright	unpolished	1.10	0.40	22.40	0.74
	unpolished	1.07	0.38	30.00	0.70
	milled	0.82	0.31	17.25	0.51
Fortuna	unpolished	1.90	0.51	32.00	0.84
	unpolished	1.00	0.38	30.80	0.68
	unpolished	0.97	0.37	22.53	0.80
	milled	0.80	0.30	18.00	0.48
Rexoro	unpolished	1.50	0.51	26.60	0.70
	milled	0.60	0.30	17.00	0.50
Nira	unpolished	1.65	0.55	24.50	0.80
	milled	0.74	0.35	19.00	0.44

---

* The Food and Nutrition Board is concerned with the broad problems of nutrition in the United States, particularly under war conditions. It has had a large responsibility in connection with the establishment and promotion of enrichment of bread and flour. It has given consideration to rice for an essentially similar reason.

and the Food and Nutrition Board felt the need for the establishment of a standard for unpolished rice. To this end the Board addressed itself to the Grain Products Branch of the War Food Administration, urging the consideration of a suitable standard for an unpolished grade of rice.

There is no ready method whereby the vitamin and mineral content of unpolished rice can be estimated by visual inspection, and a standard requiring other than the simplest chemical laboratory test would not be satisfactory because of lack of facilities in the warehouses and because of the excessive time that would be consumed in grading rice. It would be most desirable to develop a simple test for the degree of undermilling. Without it one cannot specify a rice to a definite content of the essential nutrients by description of the degree of milling. One must resort to chemical analysis for each nutrient.

Rice has been tested at successive stages of milling and we thus have a general idea as to the point at which milling should be interrupted to obtain the best compromise between appearance on the one hand and nutritional quality on the other. In an endeavor to define unpolished rice more closely, data were obtained regarding the loss of weight of the grain and the loss of ash, thiamine, riboflavin, niacin, and fat in the course of the milling process. An attempt was then made to correlate these values with the degree of milling. This study included 19 samples of rough, brown, unpolished, and head rice (milling season 1943-1944) of six different varieties from six different mills in the rice-producing areas of Louisiana, Arkansas, Texas, and California. The weight of grains at successive stages was obtained by weighing 250 kernels from each sample.

The results of this investigation are given in Table 13 and the data clearly show that the nutrients decline progressively during milling. Below are given the average contents of these nutrients in rough and head rice and their percent losses as compared with the weight loss during the milling process.

	Av. Wt. of 250 Kernels Grams	Ash Percent	Ether Extract Percent	Thiamine µg/g	Riboflavin µg/g	Niacin µg/g	Iron µg/g
Rough	6.01	6.06	2.06	2.97	0.90	51.6	31.20
White	4.96	0.70	0.53	1.00	0.43	22.0	5.87
Loss (percent)	17.50	88.40	74.20	66.30	52.20	57.2	81.10

These results show that the overall percent loss of the nutrient constituents of the grains during the milling process as a whole is only 3 to 5 times the percent weight loss. However, in the late stages of milling, the proportionate average percentage declines in weight versus those for nutrients from the unpolished to the head rice are quite different. The percent losses at this stage for all samples of Table 13 are as follows:

Weight of 250 Kernels Percent	Ash Percent	Ether Extract Percent	Thiamine µg/g	60 Riboflavin µg/g	Niacin µg/g	Iron µg/g
2.05	17.0	34.9	21.4	13.6	24.8	50.1

Here the percent nutrient losses are 6 to 25 times as great as the weight loss. *Indeed*, Table 13 shows instances in which the percent thiamine loss is 30 to

TABLE 13
COMPARATIVE DECLINE OF NUTRIENTS DURING MILLING OF RICE
(1943–1944 milling season)

No. of sample	Variety and type of rice	Weight of 250 grains Grams	Ash Percent	Ether extract Percent	Thiamine μg/g	Riboflavin μg/g	Nicotinic acid μg/g	Iron μg/g
1	Rexoro[a]							
	rough	5.29	5.84	2.15	2.70	0.84	46.29	27.90
	brown	4.27	1.28	1.98	3.00	0.63	42.18	23.90
	undermilled	4.05	0.80	0.81	1.10	0.45	31.94	17.90
	head	4.00	0.73	0.58	0.73	0.38	26.04	13.60
2	Zenith[a]							
	rough	5.95	5.56	2.07	3.82	0.76	51.71	29.50
	brown	5.08	1.20	2.00	3.09	0.70	44.80	22.30
	undermilled	4.67	0.72	0.80	1.09	0.51	30.58	14.30
	head	4.62	0.41	0.41	0.73	0.38	24.00	7.10
3	Rexoro[b]							
	brown	4.12	1.33	2.32	2.91	0.76	43.30	30.70
	first break	3.96	0.94	1.04	1.40	0.70	27.10	19.60
	second break	3.95	0.92	0.99	1.27	0.51	25.30	17.90
	head	3.93	0.86	0.48	1.09	0.42	24.34	4.28
4	Zenith[c]							
	rough	6.03	6.75	2.54	3.55	0.86	54.68	25.00
	brown	5.08	1.67	2.34	4.05	0.72	43.00	17.90
	undermilled	5.01	1.57	1.64	2.18	0.59	36.90	17.00
	undermilled	4.72	1.50	1.53	1.73	0.56	33.80	12.50
	first break	4.63	1.47	1.50	1.70	0.54	31.30	11.75
	second break	4.61	1.17	0.93	1.36	0.46	26.70	10.25
	head	4.51	1.06	0.64	1.27	0.44	21.00	6.10
5	Blue Rose[c]							
	rough	7.70	5.81	1.90	3.82	0.76	59.40	39.30
	brown	6.15	1.56	2.20	3.55	0.72	52.50	29.30
	first break	5.83	0.95	0.88	1.30	0.58	23.17	19.30
	second break	5.76	0.78	0.76	1.09	0.51	22.06	13.60
	head	5.53	0.70	0.70	0.82	0.43	16.00	1.78
6	Zenith[a]							
	rough	6.22	6.62	2.12	3.91	0.81	52.50	41.40
	brown	4.83	1.28	2.36	3.45	0.66	47.90	35.70
	undermilled	4.61	0.92	0.82	1.18	0.46	31.05	17.50
	head	4.53	0.53	0.58	0.91	0.36	22.41	5.30
7	Blue Rose[a]							
	rough	8.12	6.09	1.62	3.09	0.90	59.92	30.70
	brown	6.43	1.31	2.46	3.09	0.66	53.00	25.70
	undermilled	6.07	0.70	0.76	1.36	0.51	40.00	20.14
	head	5.97	0.56	0.44	0.82	0.46	24.13	9.60
8	Caloro[d]							
	rough	7.23	4.60	2.24	3.27	0.86	55.40	27.90
	brown	5.93	1.39	1.66	3.36	0.81	51.50	15.32
	first break	5.87	0.89	1.32	2.27	0.61	26.09	12.30
	second break	5.82	0.78	0.82	1.82	0.51	24.50	11.16
	head	5.26	0.56	0.50	1.55	0.46	20.15	5.35
9	Rexoro[b]							
	rough	6.00	5.99	1.66	3.09	0.94	51.24	23.60
	brown	4.41	1.30	2.44	2.73	0.66	49.00	19.30
	undermilled	4.32	1.19	1.30	1.82	0.48	41.00	15.00
	undermilled	4.26	1.12	1.22	1.73	0.44	40.00	12.90
	first break	4.23	1.08	1.12	1.36	0.40	33.85	9.30
	second break	4.21	1.03	1.07	1.27	0.38	30.00	7.70
	head	4.18	0.92	0.52	1.05	0.37	22.60	5.40

TABLE 13—Continued

No. of sample	Variety and type of rice	Weight of, 250 grains Grams	Ash Percent	Ether extract Percent	Thiamine μg/g	Riboflavin μg/g	Nicotinic acid μg/g	Iron μg/g
10	Zenith[e]							
	rough	6.08	6.30	2.38	4.10	0.86	49.00	35.90
	brown	5.13	1.51	1.72	3.50	0.62	47.00	18.00
	first break	4.72	0.84	0.74	1.22	0.57	38.70	9.30
	second break	4.67	0.81	0.62	1.18	0.46	33.20	8.00
	head	4.56	0.78	0.32	0.73	0.40	21.50	3.50
11	Rexoro[a]							
	rough	5.48	6.79	1.78	2.64	1.07	45.00	31.01
	brown	4.45	1.38	2.08	3.36	0.90	43.00	17.14
	undermilled	4.21	0.79	0.62	1.27	0.56	35.00	9.30
	head	4.16	0.70	0.44	1.00	0.46	22.50	7.90
12	Blue Rose[a]							
	rough	7.67	6.06	2.24	3.73	1.27	53.30	33.20
	brown	6.17	1.40	2.28	3.91	1.00	46.70	17.71
	undermilled	5.85	0.76	0.98	1.18	0.66	34.12	11.29
	head	5.82	0.67	0.66	1.00	0.61	21.18	3.90
13	Lady Wright[e]							
	rough	7.86	6.73	1.84	3.64	1.00	50.00	30.70
	brown	6.83	1.50	1.42	3.55	0.76	47.00	21.40
	first break	6.27	0.89	0.92	2.18	0.61	36.90	13.40
	second break	6.12	0.78	0.82	1.55	0.55	31.81	12.90
	head	6.05	0.60	0.42	1.27	0.45	22.80	6.10
14	Blue Rose[f]							
	rough	7.55	5.28	2.04	3.55	0.96	55.00	27.15
	brown	6.85	1.56	2.14	4.35	0.81	39.11	23.20
	first break	6.11	1.00	1.14	2.65	0.70	30.00	15.40
	second break	6.03	0.72	0.80	1.27	0.62	25.00	8.90
	head	5.87	0.67	0.68	1.20	0.52	21.60	4.57
15	Early Prolific[e]							
	rough	7.01	6.28	2.14	4.27	0.76	46.70	35.00
	brown	5.92	1.47	2.70	4.55	0.72	43.50	22.50
	first break	5.56	0.94	0.98	1.82	0.57	29.40	15.00
	second break	5.50	0.89	0.62	1.09	0.44	26.22	5.00
	head	5.39	0.72	0.50	0.91	0.40	21.08	3.60
16	Zenith[e]							
	undermilled	4.73	1.24	1.26	1.45	0.61	36.40	6.70
	undermilled	4.71	1.19	1.22	1.27	0.56	31.90	5.70
	undermilled	4.58	1.02	1.04	1.18	0.50	27.50	4.70
17	Blue Rose[e]							
	undermilled	5.77	1.11	1.26	2.09	0.66	37.00	10.00
	undermilled	5.73	1.07	1.16	1.91	0.56	34.80	6.71
	undermilled	5.63	0.94	1.02	1.82	0.51	31.70	5.35
18	Caloro[d]							
	first break	6.05	0.91	1.46	2.64	0.54	34.50	8.50
	second break	5.88	0.73	1.02	1.82	0.50	30.00	7.60
19	Early Prolific[e]							
	undermilled	5.68	1.08	1.12	2.40	0.55	32.00	9.12
	undermilled	5.56	1.91	0.84	1.50	0.45	31.70	7.00
	undermilled	5.33	0.85	0.74	1.40	0.40	28.00	6.15

---

[a] Obtained through courtesy of Comet Rice Mills, Beaumont, Texas.
[b] Obtained through courtesy of Beaumont Rice Mills, Inc., Beaumont, Texas.
[c] Obtained through courtesy of the Arkansas Rice Growers Coop. Association, Stuttgart, Ark.
[d] Obtained through courtesy of Rosenberg Bros. & Co., San Francisco, California.
[e] Obtained through courtesy of the Walton Rice Mill, Stuttgart, Arkansas.
[f] Obtained through courtesy of the Rickert Rice Mills, Inc., New Orleans, La.

40 times the percent weight loss. This means that the rate of decline in the content of nutrients is greatest at the stage where the rate of weight loss is least. Obviously weight loss is a very insensitive index of the degree of milling in the nutritional sense. It cannot be recommended as a means of control.

None of the other indices which we have tried seems to offer better promise. Inspection of Table 13 reveals that there is a poor correlation between ash content and the content of the nutrients; for example, thiamine. The correlation of fat content with thiamine content is better, though not very good. Moreover, since a fat analysis is slow and requires a competent analyst and precautions against fire hazard from ether, it does not appear very practicable. The time factor also applies to assays for thiamine, riboflavin, niacin, or iron as means of controlling the degree of milling. While an assay is under way scores of barrels of rice would pass through the mill and the mill adjustments would be altered by attrition and vibration. The results of the tests would then merely serve to indicate that over-milling had occurred, if such were the case, but would provide no warning in advance. Accordingly, a virtually instantaneous test is needed for proper milling control. Unless such a test is developed, the outlook for an adequate nutritional quality control of unpolished rice is not auspicious.

A consideration of the scouring process in the so-called huller reminds us that there is no feature of the process which tends to interrupt or reduce the attrition on a particular grain of rice when that grain has reached the proper stage. All the grains in the huller continue to be subjected to attrition as long as they remain in the huller. The assumption is made that all grains are in the same state of milling when they enter the machine and that there is a statistical probability that they will be equally abraded during their passage through the machine. Both of these assumptions are only approximately true. If the bran adheres more strongly to one grain than to another the chances are that the former grain will enter the huller with more bran on it and that passage through the huller will only accentuate the contrast. If milling is achieved by passage through a succession of hullers, as is usually the case, it would be of great help if a process of sorting could be applied between each stage and the next, whereby the grains could be closely reclassified according to the fraction of the bran which they still retain. No scheme for doing this practicably has been devised.

In practice the miller constantly inspects visually the rice stream flowing from each huller and adjusts it for a little looser or a little tighter milling according to some mental standard of color which he endeavors to keep in mind. Most millers express considerable confidence in their ability to match a predetermined standard of milling. While it must be conceded that by training they acquire an amazing ability to detect fine differences in degree of whiteness, analysis of the products they produce does not confirm their predictions with exactitude. One miller has suggested the use of a separate motor on each huller and an ammeter which would indicate constantly the energy consumption. This might help the constancy of milling very greatly, but it does not reach the fundamental problem of equality from grain to grain.

Standard for Unpolished Rice

At a meeting of the members of the Rice Millers' Association at New Orleans, La. (see footnote page 41), a set of eighteen unpolised rice samples of known thiamine, riboflavin, niacin, and ash content was displayed. These samples represented a wide range of undermilling, as could readily be seen from their appearance. Table 14 gives the data expressed in milligrams per pound. The samples were arranged in a sequence according to their thiamine content, ranging from 1.21 mgs. for sample 11 to .44 mgs. for sample 9. A choice was made of a sample representing the best compromise between marketability as judged by appearance on the one hand and nutritional quality as shown by thiamine content on the other hand.

TABLE 14

NUTRIENTS IN UNPOLISHED RICE

Sample number	Variety	Ash percent	Thiamine mg. per lb.	Riboflavin mg. per lb.	Niacin mg. per lb.
11	Zenith[a]	0.90	1.21	.19	11.97
3	Early Prolific[b]	0.90	.96	.23	14.90
1	Early Prolific[b]	0.76	.96	.22	8.55
16	Rexoro[c]	1.00	.86	.26	14.54
6	Fortuna[b]	0.84	.86	.23	14.40
10	Zenith[a]	0.80	.78	.16	11.03
18	Nira[d]	0.80	.74	.25	11.03
15	Blue Rose[c]	0.80	.72	.25	11.79
4	Early Prolific[b]	0.86	.71	.17	12.15
13	Zenith[b]	0.80	.70	.18	11.07
17	Rexoro[d]	0.70	.68	.23	11.97
2	Early Prolific[b]	0.70	.68	.20	8.10
14	Zenith[a]	0.60	.63	.23	13.61
12	Early Prolific[b]	0.90	.63	.18	11.48
5	Lady Wright[b]	0.74	.50	.18	10.08
8	Lady Wright[b]	0.70	.48	.17	13.50
7	Fortuna[b]	0.68	.45	.17	13.86
9	Fortuna[b]	0.80	.44	.17	10.13

[a] Obtained through courtesy of the Producers Rice Mill, Stuttgart, Arkansas.
[b] Obtained through courtesy of the Arkansas Rice Growers Coop. Association, Stuttgart, Arkansas.
[c] Obtained through courtesy of the Comet Rice Mills, Beaumont, Texas.
[d] Obtained through courtesy of the Beaumont Rice Mills, Beaumont, Texas.

Sample No. 10[*] was selected as the least-milled rice acceptable to the trade and an agreement was reached that a minimum thiamine level of 0.8 milligrams per pound be proposed as a standard for unpolished rice. The Food and Nutrition Board later inspected the same samples and data and agreed to this proposed standard as describing what is immediately attainable in an unpolished rice. The gain in nutritional quality by undermilling was disappointing to the Board, especially in view of the prospect of thiamine losses during storage (see page 53). It was further evident that the standard can be used under present conditions only for visual comparison purposes. Rice samples of similar appearance may vary considerably in thiamine content as well as in the content of other nutrients. In the final action of the Board, the greater yield of unpolished rice as compared with fully milled rice was emphasized in the following recommendation to the War Food Administration:

---

[*] Credit is due Mr. W. D. Smith, Supervisor, Food Distribution Administration, U. S. Dept. of Agriculture, for aid in selecting this sample.

> "*RESOLUTION* January 29, 1944.
>
> Resolved that the Food and Nutrition Board of the National Research Council regards the promulgation of a standard for unpolished rice as a useful measure for the conservation of food supply during the war emergency because avoidance of polishing increases the yield of rice and improves the nutritional value of the product."

After the receipt of a copy of this resolution, the War Food Administration issued, effective April 1, 1944, its standard stated in the following terms:

> "Milled rice shall be whole or broken kernels of rice of the classes specified in these standards, from which, (a) in the case of milled rice other than milled rice of the special grade unpolished milled rice, the hulls and practically all of the germs and bran layers have been removed, or (b) in the case of milled rice of the special grade unpolished milled rice, the hulls and the outer bran layers, but not the inner bran layers, and a part of the germs, have been removed."

Clearly such a standard is not susceptible of rigorous enforcement and it must be anticipated that unpolished rice produced under it will of necessity be variable in nutritional quality. The emphasis of the Food and Nutrition Board on undermilling as a war emergency measure appears well justified by the facts. It is increasingly doubtful that undermilling can be relied on as a long-term, peacetime improvement in rice quality.

Earle Process of Undermilling

The Earle process (U. S. Patent 2,232,696, Feb. 25, 1941, to Theodore Earle) which is described as a peeling method, is not in commercial use. The rice is fed continuously into a tubular mill. The lining of this mill is rubber, about ¼ inch thick. Inside the mill several loose rubber-covered steel rods

TABLE 15

THIAMINE, RIBOFLAVIN, AND NIACIN IN "PEELED" RICE

	Thiamine µg/g	Riboflavin µg/g	Niacin µg/g
Brown rice	3.80	.47	53.0
Peeled rice (.27% bran removed)	3.00	.31	47.0
Brown rice	4.26	.52	49.0
Peeled rice (.47% bran removed)	2.73	.31	36.0
Brown rice	3.20	.53	47.2
Peeled rice (.57% bran removed)	2.55	.33	30.0

of 2 inches diameter are placed. These rods extend the full length of the mill shell and roll within it. The rods do not cascade, so the action is entirely one of rubbing rather than impact. As the peeled rice comes from the mill, it is passed in front of a blower and the bran and trash blown out. The peeling of rice is essentially a special form of undermilling which aims to limit breakage to a minimum and to retain valuable nutrients. More or less bran can be removed depending on the peeling time. Table 15 gives results obtained with this method.

No special heat treatment of the rice takes place, and it may be expected that this rice will be susceptible to attack by weevils and to rancidification due to presence of fat in the remaining bran layers and embryos.

DETERIORATION OF RICE IN STORAGE

Deterioration of rice in storage is a subject of very great importance. A reading of the literature gives one a strong impression that rice is more subject to deterioration than wheat. To what extent this is true, to what extent it reflects intrinsic properties of the two grains, and to what extent differences in the usual conditions of storage and use of the two grains are responsible, are questions to which no definitive answer can be supplied at present. One should remember that rice is adapted to cultivation only in areas of abundant water and, since any staple food tends to be eaten most in the areas where it is produced, the regions in which rice is stored tend to be much warmer and more moist than those where wheat is prevailingly stored. It is quite possible that this fact alone accounts for the apparently greater perishability of rice.

Grain spoilage must be considered from three standpoints: (a) attack by insects, especially weevils, (b) rancidification, and (c) loss of specific nutrients, notably thiamine. The first two of these deteriorative factors apply particularly to brown or undermilled rice. All of them apply to rough rice to a lesser extent, since the presence of the hulls affords a considerable measure of protection. They apply least to highly milled rice because its nutritional inadequacy in certain respects makes it unattractive for insects and its low fat content reduces tendency to rancidity.

The literature on the effects of storage of grains is largely lacking in material of quantitative character. The most elaborate studies of the storage of rice are those of Kondo and Okamura.[30] They examined rice that had been stored under various conditions for periods as long as 30 years, testing for physical characters of the starch, germinating power, enzyme content, flavor of the cooked product, and vitamin B content. The last estimation involved feeding experiments with fowls. Principal conclusions were that, with a moisture content below 12 percent, rice may be stored in hermetically sealed containers for many years with little deterioration. In straw bags deterioration is serious after two years storage. The authors advocate storage in the hulled condition (to reduce volume) in dry sealed concrete silos. Under these conditions, storage up to 5 years resulted in little deterioration. These papers do not treat of insect attack in detail.

---

[30] Kondo, M., and Okamura, T. Storage of rice. Ber. Ohara Institus landwirt. Forschungen 5: 395, 407, 413 (1932); 7: 471, 483 (1937).

Insect Attack

The total damage by insects to stored grain in the United States has been estimated at $300,000,000 annually. This is due principally to weevils and beetles which deposit their eggs in the outer bran layers of the grain, whence they develop. Vast amounts of wheat are damaged by this means and control of weevils in flour mills and warehouses is a problem of great importance. White flour is very little subject to attack, but flours which retain more or less of the bran coats and germs rapidly become infested, especially in warm weather. The weevils and their eggs may be removed from fine ground flour by resifting it.

A similar though somewhat less serious problem exists in rice mills in this country. Rice is usually stored for long periods only as rough rice or as fully milled rice. The former is much, though not completely, protected by the hulls, the latter by absence of the full complement of nutritional factors required for growth of the insect. Many modern rice mills practice some system of fumigation against insects; this, however, is applied principally to finished goods in carton package form. It is especially necessary in preparing brown rice for the retail market. Methyl bromide, hydrocyanic acid, and carbon disulfide are chiefly used. Rice bran and polish attract weevils quickly, but these products are rarely stored in rice mills for long.

Reference is encountered in the European literature to the use of non-silicious, non-toxic mineral dusts, for example, rock phosphate, for preventing infestation. The dusts are mixed with grain during storage and are said to destroy insects already present as well as to prevent further infestation by causing a film of the dust to coat the insects' body surfaces. The dusts are removed mechanically before converting the grain to finished form for human use. New and more effective dusts for this purpose have recently been mentioned.[81] We have not, however, encountered this practice in the rice mills of the United States.

Rancidity

Rice deteriorates in odor and flavor with long storage, largely because of development of rancidity in the contained fats. Rancid odors which may become very foul are most prominent in rice bran and polish if these are kept for a long time and provided weevils do not first consume them. Unhulled rice is greatly, though not completely, protected by the enclosing hulls. White rice, being very low in fat, develops noticeable rancidity only after very long storage under unfavorable conditions. The rancidity problem is therefore largely associated with brown rice, undermilled rice, and the various types of parboiled rices. In all these instances it is a problem of first importance, since the grain may be rendered quite inedible, or at least unsaleable, after long storage.

---

[81] Kitchener, J. A., Alexander, P., and Briscoe, H. V. A. Method of protecting cereals and other stored foodstuffs against insect pests. Chemistry and Industry 62: 32 (1943): Wigglesworth, V. B. Action of inert dusts on insects. Nature 153: 493 (1944).

Rancidity[32] in grain is regarded as due primarily to changes by atmospheric oxidation of the fat present. These changes affect predominantly the unsaturated fatty acids by attack at the double bonds with intermediate formation of oxides or peroxides, which then split to form aldehydes and fatty acids of shorter chain length. A considerable number of modifications of the fundamental theory of rancidification have been proposed and it is probable that a number of reactions occur simultaneously in the deterioration of fatty foods. These questions remain controversial even in the case of isolated fats and oils and are even more uncertain in the case of grain. There is reason to think that rancidification is autocatalytic, rising slowly at first and then much more rapidly. Enzymic liberation of free fatty acids may play a role in the rancidification of rice, but it is not the dominant one, since rice that has been steamed is still quite capable of becoming rancid. Another possible, though less probable, factor is the action of microorganisms. Rancidification is hastened by exposure to light. It is slowed by storage at low temperature, is little affected or is even favorably affected by humidity, but can be greatly retarded by limiting the supply of oxygen through hermetic sealing or storage in inert gases.

Practical preventive measures against rancidity are not numerous. Shipment and storage of rice in unhulled form is recommended by many authorities and is practiced generally by the trade both in the United States and in the Orient. Another effective expedient is prompt milling to a white rice stage, but this involves familiar serious losses of nutrient values. It is difficult to judge from the literature the seriousness of rancidity in the case of parboiled rice used so extensively in India. There is reason to suspect that the users of parboiled rice are less sensitive to rancid odors than users of raw rice. The proposals of Kondo and Okamura[30] regarding storage of rice in dry sealed silos may have value for bulk storage, but such storage would be unsuitable for the purpose of constant daily withdrawals for sale or use. Packing in small retail air-tight containers, especially in inert gases, would be effective, but these methods like those of cold storage are far too expensive to be applied to staple supplies of rice for great masses of populations.

Losses of Nutrients in Storage of Rice

Several investigators have reported on the effect of storage on the nutritive qualities of grain products other than rice. The effect of storage on protein in corn has been reported[33] and it was found that ground corn and whole shelled corn in a storage period of 2 years showed a decrease in the solubility of proteins, a partial breakdown of the proteins, indicated by a decrease in true protein content, and a decrease in digestibility. The extent of the changes was influenced by temperature, type of container, duration of storage, and the nature of the material stored. Samples stored at 76° F. were affected more than those stored at 30° F., and those in bags more than those in sealed glass jars. Changes in the ground corn were greater than those in the whole shelled corn. Significant decreases in feeding values were also found.

---

[32] Lea, C. H. Rancidity in edible fats. Great Britain Dept. of Scientific and Industrial Research, Special Report No. 46 (1938).

[33] Jones, D. Breese, Divine, J. P., and Gersdorff, Chas. E. F. The effect of storage of corn on the chemical properties of its proteins and on its growth-promoting value. Cereal Chemistry 19: 819 (1942).

The effect of storage on thiamine content and on development of rancidity in wheat germ has been reported.[34] Wheat germ samples with moisture content varying between 8.0 and 26.5 percent were stored in air in sealed tins. The storage temperatures used were −40°, −15°, 0°, 15°, 30°, 60°, and 75° F., and the storage time was six months. Proteins were believed to be the chief factor involved in wheat germ spoilage. Very little loss in thiamine occurred even when the wheat germ had become inedible because of rancidity and protein spoilage.

In research on storage of rice, it was found that the starches are affected. These studies were concerned with cooking qualities and digestibility of stored as compared with unstored rice. The results showed that the cooking quality was improved in samples stored in air-tight containers or under anaerobic conditions. Well-stored rice grains swell on cooking to about 4 times the original volume, while the unstored grains swell to scarcely twice the original volume. Well-stored rice seems also to be more digestible. The results are partly explained on the basis of changes undergone by the starch during storage.[35] The studies of Kondo and Okamura [30] previously mentioned are also pertinent in this connection.

The effect of storage on thiamine in rice has been studied by Cailleau and coworkers.[36] The samples were stored at approximately 68° F. in a dark cupboard in a ground floor laboratory, where the temperature varied but little. The rice samples were kept in muslin or very heavy paper sacks. The bran samples were kept in screw-top glass jars. It was found that, after six months storage at 68° F. under good conditions, brown rice lost from 0 to 30 percent of thiamine. Rice bran and rice polish lost 16 to 28 percent of thiamine during 6 months storage, and 50 to 67 percent after 24 months of storage. Parboiled brown and parboiled undermilled rice did not appear to lose thiamine during storage of 6 months and 3 months respectively.

A recent publication by Anheuser Busch, Inc., under date of January 22, 1945, shows surprisingly high losses of thiamine during six months storage of beans, peas, and unhulled rice, compared with wheat in whole grain form, in spite of low moisture content. On the other hand, we have data from Hoffmann-La Roche [37] showing negligible losses of thiamine in brown and converted rices during storage for 19 months at room temperature or for 500 hours at 45° C. The conflicting evidence in the literature may well be due in part to the difficulties of complete extraction for assay purposes.

---

[34] Pearce, J. A. Effect of storage on the thiamine content and on development of rancidity in wheat germ. Canadian Jour. of Research C, *21*: 57 (1943).

[35] Screenivasan, A. Investigation on rice. Current Science 6: 615 (1938).

[36] Cailleau, R., Kidder, L. E., and Morgan, A. F. The thiamine content of raw and parboiled rices. Cereal Chemistry *22*: 50 (1945).

[37] Private Communication. Siemers, G. F. Feb. 20, 1945.

TABLE 16
STABILITY OF THIAMINE IN RICE IN STORAGE

Products	VARIETY AND MILL LOT									
	Supreme Blue Rose 551[a]					Supreme Blue Rose 606[a]				
	Before	After		Loss		Before	After		Loss	
		Ground kernels	Whole kernels	Ground kernels	Whole kernels		Ground kernels	Whole kernels	Ground kernels	Whole kernels
	µg/g	µg/g	µg/g	percent	percent	µg/g	µg/g	µg/g	percent	percent
rough	3.60	2.82	2.86	21.70	20.55	3.00	2.36	2.42	21.13	18.13
brown	4.00	3.06	3.20	23.50	20.00	3.88	2.45	2.82	36.60	27.32
white	0.74	0.44	0.48	40.54	35.13	0.55	0.35	0.37	36.36	32.72
bran	33.00	20.82		36.91		33.60	11.15		65.77	
polish (brush)	27.90	15.23		48.72		26.70	13.41		50.00	
	Early Prolific 569[a]					Early Prolific 663[a]				
rough	3.43	2.75	2.86	19.82	16.32	3.00	2.33	2.41	22.33	19.66
brown	4.18	2.98	3.04	28.71	27.94	3.30	2.37	2.45	28.20	25.76
white	0.65	0.40	0.45	38.46	30.77	0.58	0.40	0.43	31.03	26.00
bran	32.20	18.82		41.55		23.90	12.25		48.74	
polish (brush)	21.30	14.55		31.70		20.00	7.55		61.22	
	Fortuna[a]					Lady Wright[b]				
rough	3.20	2.38	2.41	25.62	24.70	3.00		2.94		2.00
brown	3.24	2.33	2.40	28.21	26.00	3.50		3.45		1.42
white	0.84	0.62	0.65	26.20	22.62	0.65		0.64		1.53
bran	21.50	8.90		58.61		26.60	26.50		0.38	
polish (brush)	15.00	9.77		34.87		19.40	19.37		0.15	
	Improved Blue Rose[b]									
rough	3.07		3.02		1.62					
brown	3.00		2.97		1.00					
white	0.85		0.82		0.35					
bran	20.80	20.71		0.43						
polish (brush)	16.40	16.37		0.18						

[a] Samples (ground and whole kernels) were stored in the dark for 2⅓ years in dark brown bottles in the attic of the building.
[b] Samples were placed in cold storage (−10° C) for 2⅓ years.

The effect of storage on thiamine, riboflavin, and niacin in rice has been studied in the laboratory of the Arkansas Agricultural Experiment Station. In 1941, samples of rice and its by-products of three varieties, Supreme Blue Rose lot 551 and lot 606, Early Prolific lot 559 and lot 663, and Fortuna, were stored at room temperature in dark brown bottles in boxes in the attic of the building. Similar samples of two varieties, Lady Wright and Improved Blue Rose, were simultaneously placed in a freezer-storage locker (temperature —10° C.). All these samples were obtained from one mill. Details of the effect of storage on thiamine in these rice samples after 2½ years are given in Table 16, and the average thiamine, riboflavin, and niacin losses in the samples (whole and ground kernels) of three varieties stored in the attic are given in Table 17. The samples of bran and polish molded considerably, which may account for the high losses.

TABLE 17

AVERAGE LOSSES OF NUTRIENTS IN RICE DURING ATTIC STORAGE

	Whole kernels Loss (percent)			Ground kernels Loss (percent)		
	Thiamine	Riboflavin	Niacin	Thiamine	Riboflavin	Niacin
Rough	19.87	6.34	4.12	22.10	8.75	5.76
Brown	25.40	4.20	3.87	29.00	7.57	6.80
White	29.40	5.44	3.77	34.50	6.40	5.71
Bran	50.37	16.35	15.20			
Polish	45.30	18.00	14.60			

No significant losses of thiamine or niacin and only slight losses of riboflavin occurred during cold storage. The average percentage losses for thiamine, riboflavin, and niacin in the samples (whole kernels) kept at —10° C. are given in Table 18.

TABLE 18

AVERAGE LOSSES OF NUTRIENTS IN RICE IN COLD STORAGE

		Loss (percent)	
	Thiamine	Riboflavin	Niacin
Rough	1.81	1.98	1.10
Brown	1.21	3.84	1.95
White	0.94	1.61	1.20
Bran	0.40	1.73	1.25
Polish	0.16	1.75	1.61

Rice samples in various stages of milling were also obtained from different mills and stored in bottles during the summer of 1944 at room temperature (average 84° F.). They were samples of whole kernels of the varieties Lady Wright, Caloro, Rexoro, Blue Rose, and Zenith, and stored in glass containers in the light in the laboratory. Ground kernels, samples of the same varieties, were stored in paper bags in the dark in a closed metal container. All these samples were tested after three and after nine months for thiamine, riboflavin, and niacin. Data on stability of thiamine in samples (whole kernels and ground) of 5 varieties stored at room temperature, (range 68° F.-100° F. average 84° F.), are given in detail in Table 19. The average percentage losses are given in Table 20. Losses up to 7 percent were found after 3 months storage, and up to 15 percent in ground kernels and 13 percent in whole kernels after 9 months storage. The losses were slightly lower for whole kernels than for ground kernels.

TABLE 19

STABILITY OF THIAMINE IN RICE IN STORAGE[a]

Type and variety	Before Storage	After Three Months Ground		After Nine Months Ground		After Nine Months Whole Kernels	
		µg/g	Loss, %	µg/g	Loss, %	µg/g	Loss, %
Lady Wright							
rough	3.64	3.45	5.22	3.31	9.06	3.60	1.10
brown	3.55	3.40	4.22	3.21	9.60	3.38	5.00
unpolished	2.18	1.92	8.80	1.81	17.00	1.94	11.00
milled	1.27	1.17	8.00	1.03	18.80	1.09	14.17
Caloro							
rough	3.27	3.10	5.20	2.85	12.84	3.21	1.22
brown	3.36	3.10	8.00	3.09	8.04	2.91	13.40
unpolished	2.27	2.19	3.50	2.00	11.90	2.12	7.00
milled	1.55	1.45	6.45	1.35	12.90	1.39	10.32
Rexoro							
rough	3.25	3.00	7.70	3.00	7.70	2.96	9.00
brown	3.26	3.12	4.30	2.91	10.73	2.71	17.00
unpolished	1.30	1.27	2.30	1.09	16.15	1.11	14.60
milled	.93	.85	8.60	.80	14.00	.80	14.00
Blue Rose							
rough	3.09	2.95	4.53	2.54	17.80	2.70	12.62
brown	3.79	3.63	4.22	3.16	17.00	3.26	14.00
unpolished	1.36	1.30	4.41	1.20	11.80	1.27	6.62
milled	.82	.78	4.88	.71	13.41	.73	10.97
Zenith							
rough	3.82	3.69	3.40	3.20	16.23	3.16	17.28
brown	3.09	3.00	3.00	2.60	15.85	2.85	7.76
unpolished	1.09	1.00	8.20	.91	16.51	1.05	3.67
milled	.73	.65	9.00	.60	17.67	.61	16.52

[a] Samples of whole kernels were stored in the light at room temperature in glass containers in the laboratory. Samples of ground rice were stored in the dark in paper bags in a container in the laboratory.

TABLE 20

AVERAGE LOSSES OF THIAMINE IN RICE IN STORAGE

	After 3 months Loss (percent)	After 9 months Loss (percent) Ground kernels	After 9 months Loss (percent) Whole kernels
Rough	5.01	12.73	8.24
Brown	4.75	11.28	11.43
Undermilled	5.40	14.67	7.18
Milled	7.38	15.35	13.19

In the foregoing experiments, the conditions of storage were at least as favorable as would be encountered in commercial practice, and in general they were more favorable. Further experiments are in progress under conditions more closely approximating commercial storage and these will be reported in a later publication. (See Appendix page 76). However, it is to be anticipated that they will reveal losses somewhat larger rather than smaller than those reported above.

The average period of commercial storage of rice in the United States may be taken as about 5 months, although obviously the storage period will vary extremely, depending on the distance the rice has to be shipped, the demand for rice at the time of milling, and many other similar factors. However, it becomes evident from the foregoing study that from a nutritional standpoint stability in storage presents a major problem in the rice industry. All evidence tends to indicate that wheat, whether in whole grain, whole wheat flour, or refined flour form, is considerably more stable than rice. In the Oriental tropics the problem of deterioration of rice by all these causes is doubly important because of climatic conditions and the difficulties of technical control. The aversion of Oriental rice millers to undermilled rice because of storage difficulties cannot be dismissed as mere prejudice.

PARBOILING OF RICE

Reference has already been made (page 30) to the use of parboiled rice by the larger part of the rice-eating population of India. Only in the Northern Circars along the coast from above Madras to the boundary of Orissa is rice used in the raw state and it is this area that produces nearly all the forthright beriberi of India, according to Aykroyd and his collaborators.[12] Parboiled rice is also used exclusively in Ceylon and British Guiana and locally in many places where immigrant Indian coolie labor has demanded or preferred it. This is especially true in British Malaya, where in certain provinces the larger part of the output of mills is parboiled. The Indian demand is also responsible for the parboiling of 12 to 15 percent of the rice annually exported from Burma. Parboiled rice is therefore a commercial product of major importance. No specific figures appear to be available, but it seems quite possible that parboiling is applied to a fifth or even more of the world's annual rice crop. Parboiled paddy is offered for sale in large volume in the markets of many cities of eastern India, where it is purchased for home milling.

The parboiling process is an ancient tradition. Presumably its original purpose was to facilitate the removal of the hulls. The grains are swollen by soaking in water and subsequently dried, usually in the sun. Often steaming follows the soaking. The hulls are loosened in either case so that they are removed more readily by pounding. It was only subsequently discovered by observations on the incidence of beriberi, which have been reviewed by Vedder,[10] that there is a nutritional advantage in the parboiling of rice. This advantage was ascribed by Vedder and others before him to greater retention of the bran after parboiling, since the bran is toughened thereby and is less readily removed. The nutritional merit of parboiling was later more fully explained by Aykroyd and others as described below.

The parboiling process is by no means highly standardized.[28] It may consist of merely soaking in cold water for several days in a concrete tank and subsequently spreading out on packed earth or a concrete floor and drying in the sun. In more systematic commercial operations, steam is blown through the paddy after steeping until the husk slightly dehisces. In this operation the surface starch is partly gelatinized. Often the steeping is carried out in hot water for 24 hours or less. Charlton recommends that water at 180° F. flow onto and through the paddy till a temperature of at least 140° F. is attained at the coolest point in the tank. Two steel boiling tanks and a battery of six concrete steeping tanks, all tanks having a capacity of 1000 gallons each, are indicated as appropriate. By this means, the steeping process is shortened to not over 36 hours and, even more important, the generation of foul odors due to bacterial action is avoided. It would appear that hot steeping might greatly improve or at least modify the flavor of the finished grain.

Another version of the parboiling process is used in Malaya, principally for consumption by Indian immigrant laborers. No steeping is involved. The paddy is merely heated in steel cylinders by steam under pressure of 20 pounds per square inch for 10 minutes and then quickly dried and milled as usual. This method is practiced particularly in government mills.[29] Few data are available on the nutritive merit of rice so steamed. "Steaming" of rice is understood to be under commercial-scale trial in Chungking under government encouragement, but no particulars of the process are presently available. In our limited experience, steaming of rice appears almost as effective as steeping and steaming for conserving the nutrients.

The flavor and other characteristics of parboiled rice are unquestionably strongly preferred by the Indians who are accustomed to it, as evidenced by the demand for it by expatriates in Malaya and the islands of the Pacific. It seems equally certain that it is heartily disliked by people who have long used raw milled rice. To the untutored Westerner, the flavors of the cooked products do not appear to differ conspicuously. The odor of the parboiled product, however, is noticeable in the raw state, especially if the rice has been kept in a closed container for some months. It appears as a rancidity to which raw milled rice of an equal apparent degree of decortication is less subject. Attempts to introduce parboiled rice in China have met with disfavor. It is, however, quite possible that proper choice of methods and the exercise of suitable controls in parboiling and subsequent storage may mitigate the distaste for it and make it commercially acceptable. This can only be determined by persistent long-term commercial market trials.

---

[28] Charlton, J. Prevention of nuisances caused by the parboiling of paddy. Bulletin 46, Agricultural Research Institute, Pusa, Calcutta, 1923.

[29] Jack, H. W. Rice in Malaya. Bulletin 35, Dept. of Agric. Federated Malay States, 1923. Page 31.

Nutrients in Parboiled Rice

Aykroyd[40] showed that parboiled rice retains a considerable proportion of its thiamine and phosphorus content even when highly milled, and suggested that some of the vitamins contained in the germ and pericarp diffuse into the grain during the process of soaking and steaming. Subrahmanyan and co-workers (1938)[41] made a study of the effect of milling on the chemical composition and commercial qualities of raw and parboiled rices. They concluded that, with the same degree of milling, parboiled rice is usually richer in nitrogen and phosphorus than raw rice, and part of the nitrogen and of the phosphorus originally present in the germ is transferred to the endosperm. Parboiled rice has a higher ash content than raw rice milled to the same extent, while smaller losses of nitrogen or of phosphorus occur in parboiled rice than in raw rice on repeated washing in connection with cooking.

TABLE 21

THIAMINE, RIBOFLAVIN, AND NIACIN IN MILLED PARBOILED AND MILLED RAW RICE

Variety	Thiamine milled parboiled μg/g	Thiamine milled raw μg/g	Riboflavin milled parboiled μg/g	Riboflavin milled raw μg/g	Niacin milled parboiled μg/g	Niacin milled raw μg/g
Nira	1.35	....	0.47	....	49.00	....
Nira	....	0.59	....	0.30	....	20.6
Caloro	1.61	....	0.33	....	45.20	....
Caloro	....	0.65	....	0.28	....	18.5
Indian	1.74	....	0.30	....	45.00	....

Parboiling also improves the milling quality of rice varieties. Aykroyd and co-workers (1940)[12] found that parboiled rice, even when highly milled, retains most of the thiamine and nicotinic acid originally present in the unmilled grain and only about 50 percent of the vitamins are lost during washing and cooking. They highly recommend the use of parboiled rice.

Screenivasan[42] offers the following explanation of the fact that parboiled rice is more nutritious than raw rice: During the process of parboiling, the endosperm of the grain swells and imbeds some of the bran constituents so that they are generally preserved in the kernel even after milling. Further, commercial parboiled rice in India is prepared only from coarse rice varieties that have thicker bran layers than ordinary fine varieties, and they do not mill so well. Finally, commercial parboiled rice is usually undermilled; the parboiling makes the outside of the grain tough and therefore it is less easy to polish parboiled rice.

---

[40] Aykroyd, W. R. The effect of parboiling and milling on the anti-neuritic vitamin (B_1) and phosphate content of rice. J. of Hygiene 32: 184 (1932).

[41] Subrahmanyan, V.; Screenivasan, A.; and Das Gupta, P. Studies on Quality in Rice. I. Effect of milling on the chemical composition and commercial qualities of raw and parboiled rices. Indian Jour. of Agricultural Sciences 8:459 (1938).

[42] Screenivasan, A. Food value of rice. Indian Medical Journal. Vol. 32, No. 12, 1938.

Most of the foregoing studies were performed without the benefit of the more modern analytical methods now available and were concerned primarily with the conservation of thiamine. The matter has been re-examined experimentally by one of the present authors (M. C. Kik) with results of a confirmatory character.

In Table 21 data are presented on thiamine, riboflavin, and niacin content in samples of rice parboiled in the laboratory and milled * in a miniature McGill mill, compared with samples of the same rice similarly milled without parboiling. This table shows that the milled parboiled rice has retained more of three important vitamins than the milled raw rice.

This confirms the observation of previous investigators that milled parboiled rice has higher nutritive value, not only with respect to thiamine but also as regards niacin. The advantage with regard to riboflavin is slight.

RICE CONVERSION †

There have been several attempts to modernize and improve the traditional rice parboiling process. Much the most extensive experience has been acquired by those who are identified with the so-called rice conversion process. This process originated in England and was considerably developed there by its senior inventor, Mr. Erich G. Huzenlaub. An organization called Rice Conversion Ltd. was formed to exploit the process through affiliations with firms having extensive interests and contacts in the Oriental rice trade. Negotiations were undertaken to introduce the process extensively in the Orient, but these were interrupted and postponed by the onset of World War II. The United States rights, however, were conveyed to a firm organized in Houston, Texas, of which Mr. Gordon L. Harwell is the primary technical director. This firm, originally James and Harwell, now Mars and Harwell, set up a plant in Houston about 1941 for the development and exploitation of the process. Operations at first were on a laboratory scale, but presently expanded into commercial scale operations in a plant which was gradually evolved for the purpose. This plant has been shipping converted rice in carload lots for two years past and has accordingly provided significant commercial experience.

Recently a larger plant has been erected at Houston with Defense Plant Corporation funds at a reputed cost of $625,000. It is expected that this plant will be in operation before summer of 1945 and will be capable of handling 1400 barrels of rice per day at the outset and twice that quantity ultimately. This plant will add substantially to the total milling capacity of Texas. The product is being taken exclusively by military authorities and is presumably being shipped, along with a large amount of raw milled rice, into Oriental areas where military operations are in progress.

A somewhat kindred process devised by M. Yonan-Malek is now receiving attention looking to a similar development in California. Very much less

---

* Through courtesy of Dr. C. R. Adair, Associate Agronomist, Stuttgart, Arkansas.

† With the cooperation of Dr. C. W. Ofelt, Carnation Company, Milwaukee, Wis. Formerly technologist, Mars & Harwell Company, Manufacturers of Converted Rice, Houston, Texas.

extensive operations of this process have so far been carried out. At the outset a prime objective in its development was the production of canned cooked rice, but the process appears potentially adapted to the production of milled rice of a parboiled type.

A reading of the patents on these two processes does not readily reveal a clear distinction between them. We are unable to point out clear-cut and obvious evidence of fundamental invention over some of the traditional processes in use in the Orient, nor have these questions been adjudicated by the courts so far as the present writers are aware. Our interest in the processes is confined to the fact that their existence has led to large scale exploitation of parboiling with reasonable technological controls, especially in the case of rice conversion. The sale of such rice in the United States and in the Orient must do much to evaluate its commercial acceptability and competitive feasibility.

The rice conversion process [48] is essentially a modernized parboiling method. Rough rice or paddy is cleaned by being passed over a separator to remove fine dirt, large stones, and straw. It is then passed through another separator which removes the whole and broken hulled rice as well as any remaining fine dirt. Finally, it is subjected to aspiration to remove as much of the chaff and extremely light paddy as possible. Formerly this was followed by a further separation through flotation of the remaining light-weight rice and hulls containing only partly developed kernels. This was accomplished by introducing the rice into a trough of turbulent water, where the light-weight kernels rose to the top to be floated off while the heavier grain was removed from the bottom of the trough by an inclined screw conveyor. At present only dry mechanical processes are used for cleaning.

The cleaned paddy is introduced into a large vessel which is then evacuated (to 25″ or more) for a period of at least ten minutes. Hot water (75-85° C.) to an amount about one-third greater than the weight of paddy is then introduced under a pressure of 80 to 100 lbs./sq. inch and the rice is steeped under these conditions, with recirculation of the water, for a period ranging from 120 to 165 minutes. The times and temperatures required for steeping are said to depend upon the variety of rice being processed, moisture content, the length of time it has been in storage, and the color desired in the final product.

The steeping water is drained off and the steeped paddy is introduced into a large cylindrical, rotating, steam-heated vessel, which is then partially evacuated and the paddy heated for a short time. At this point dry direct steam is introduced and the paddy is heated in this manner for a few minutes. The steam is then blown off and a vacuum of 28″ to 29″ applied. The product is dried under vacuum in the rotating steam-jacketed vessel until a moisture content of slightly less than 15 percent is attained. Final drying is done at atmospheric pressure. Recent work indicates that it is possible to dry the product throughout at atmospheric pressure without damage to its milling properties, provided the grain temperatures attained never exceed 145° C.

---

[48] Patents:

British No. 519,926, 4/10/40, to Erich Gustav Huzenlaub and John Heron Rogers.
British No. 522,353, 6/17/40, to Erich Gustav Huzenlaub and John Heron Rogers.
U.S. P.O. No. 2,239,608, 4/22/41, to Erich Gustav Huzenlaub, et al.
U.S. P.O. No. 2,268,486, 12/20/41, to E. G. Huzenlaub.
U.S. P.O. No. 2,287,737, 6/23/42, to Erich Gustav Huzenlaub and John Heron Rogers.

A descriptive pamphlet may be obtained from Rice Conversion, Ltd., 14-19 Leadenhall St., London, E. C. 3.

The hot, dry "converted" paddy is placed in bins and cooled by passing air through it and allowing it to remain in the bin for at least eight hours before milling. This "tempering" period is necessary in order that a state of moisture equilibrium throughout the berry may be attained.

The converted rice is milled in the usual way. The paddy is passed through shellers, then through Engelberg "hullers," and finally is cleaned up on a pearling cone. Suitable aspirations are performed between operations. Smaller amounts of bran and polish are obtained than from milling of unconverted rice, which suggests that converted rice is undermilled although this is not evident from its appearance.

The finished product is not coated and is of a yellowish color. Examination of the smooth, vitreous, translucent grain under a microscope, with polarized light, indicates that the starch of the outer part is gelatinized. The grain cooks to a product which appears practically as white as any cooked rice. Comparison in the cooked state with rice that has been highly milled without parboiling reveals only a barely discernible yellow cast. There is said to be a low percentage of breakage during the milling and the kernels are more resistant to insect infestation, which is favorable for long-distance transportation and for storage.[44]

Laboratory Tests of Rice Conversion

Rice conversion has so many potentialities that the process was deemed worthy of a systematic investigation. This work was begun in the laboratory in the fall of 1941 and later extended to plant operations through the courtesy of Mars and Harwell Company. In Table 22 are presented data of preliminary laboratory experiments with rough rice treated according to the principles of rice conversion. The following procedure was used: A 60-gram sample of rough rice was milled raw and analyzed for thiamine, riboflavin, and niacin. Eleven other 60-gram samples of the same batch of rice were "converted" separately with slight variations in temperature, pressure, and duration of treatment. After conversion, these samples were milled to the same degree of milling as the raw milled sample, and all were analyzed for thiamine, riboflavin, and niacin. This was repeated with another batch of rough rice of which two samples were "converted" and milled while a third was milled to the same degree without conversion. Both results indicate that the "converted" samples are much higher in thiamine, riboflavin, and niacin than are the raw samples. Treatment at 60 pounds pressure at a temperature of 70° C. for two hours gave satisfactory results.[44a]

---

[44] *Kik, M. C.* The story of rice conversion. The Rice Journal. (March and April 1942)

[44a] *Kik, M. C.*, and Van Landingham, F. B. The influence of processing on the thiamine, riboflavin, and niacin content of rice. Cereal Chemistry 20: 569-572.

The processing was done with the aid of an iron chamber which could be used as either a vacuum or a pressure chamber. A compressed air tank furnished up to 60 lbs. pressure, and steam was obtained from the heating plant. The vacuum chamber was connected with the pressure tank and, through another connection, with a motor vacuum pump. A distillation apparatus with receiving flask placed between the vacuum chamber and the pump collected the moisture that was drawn from the material placed inside the chamber. Through another inlet, hot water could be introduced into a small vessel containing the sample of rough rice placed within the chamber. After the processing, the rice was vacuum dried, following which it was dried overnight in the laboratory with an electric fan. The milling * was done with the aid of a McGill miller for small samples. This mill was equipped with a constant pressure device (consisting merely of a series of weights placed on the pressure cup) so as to make it possible to mill the samples in a uniform manner and to the same degree.

TABLE 22

THIAMINE, RIBOFLAVIN, AND NIACIN IN RAW AND CONVERTED MILLED RICE. (Laboratory)*

Laboratory Sample	Thiamine		Riboflavin		Niacin	
	raw μg/g	converted μg/g	raw μg/g	converted μg/g	raw μg/g	converted μg/g
0	.82		.285		24.3	
1		2.42		.380		44.0
2		2.90		.456		52.0
3		2.32		.390		48.8
4		2.14		.364		45.3
5		2.23		.356		46.9
6		1.99		....		43.1
7		2.16		....		....
8		2.90		.401		51.2
9		2.47		.401		43.5
10		1.90		.349		33.9
11		2.29		.400		48.9
18	.53	....	.317	....	15.1	....
16		2.46		.520		46.8
17		2.73		.500		39.5

* Credit is due Dr. C. R. Adair, Assoc. Agronomist, U. S. Dept. of Agriculture, Bureau of Plant Industry, Rice Branch Experiment Station, Stuttgart, Ark., for his valuable assistance in milling some of these samples.

Studies of Commercial Conversion

The foregoing laboratory studies of rice conversion were extended to plant operations by the cooperation of Mars and Harwell Company. Their plant at Houston, Texas, was visited four times during 1942-1944 and all details of the process were disclosed to us. In addition, numerous samples were supplied us of identical batches of rice in the converted and unconverted states. The converted samples obtained during 1942 came from the pilot plant. Later, after the operation of the manufacturing plant was inaugurated in September 1942, we secured samples from that source. We are greatly indebted to the management and especially to Mr. Gordon L. Harwell, General Manager, and to the inventor of the process, Mr. Erich G. Huzenlaub, for all this assistance.

---

* Credit is due Dr. C. R. Adair, Associate Agronomist, Stuttgart, Ark., for the milling of some of these samples.

Table 23 gives the nutrient contents of the various mill products of two lots of Rexoro rice obtained from the pilot plant in 1942. Tabe 24 shows similar data on four lots of rice obtained from the manufacturing plant in 1943. These data show that the finished converted rice has much higher retention of these vitamins than unconverted rice. The content of these vitamins in bran and hulls from converted rice is lower than in those from unconverted rice. This shows that the higher retention in the endosperm is at the expense of the outer layers of the kernel.

Table 25 presents data on the thiamine, riboflavin, and niacin content in the rough and milled states of 25 samples of converted rice from the manufacturing plant. All these samples were from the same lot and variety, Rexoro, except batch numbers 543, 544, 581, and 540, which were of the Nira variety. On the average the thiamine, riboflavin, and niacin contents per unit weight of the converted rices were 92, 71, and 77 percent respectively of the corresponding contents of the rough rices. "Retention" is given on this basis in Table 25. However, the net conservation of these nutrients was less, as a result of the fact that the hulls making up 20 percent of the rough rice and the bran making up about 10 percent of the rough rice both contained appreciable amounts of these nutrients which were discarded. By the use of Table 24 one can calculate approximately the discards which must have been involved. Correcting for these we can say that about 70 percent of the thiamine, 50 percent of the riboflavin, and 60 percent of the niacin present in the rough rice is conserved in the converted rice. Compared with commercial brown rice, converted rice may be said to contain about 85 percent as much thiamine and niacin and about 70 percent as much riboflavin. This is clearly a creditable performance.

Effect of Conversion on Milling Quality

The milling quality of 13 samples, of two varieties, of which 8 were Rexoro and 5 Nira, (converted and unconverted) was determined by means of the Smith shelling device. This is officially used by the U. S. Department of Agriculture[45] in determining grades of rough rice (paddy) for the Southern Rice Industry in the United States. The method is as follows:

Accurately weighed (50 gram) samples of rough rice are given a definite number of strokes of equal force and friction with a weighted block upon a prescribed curved surface. The surfaces of these two frictional elements are covered with leather and when wear occurs they are renewed to provide a constant type of surface to avoid error in the machine's result.

---

[45] U. S. Department of Agriculture, Circular No. 48, October 1928.

TABLE 23

COMPARISON OF THIAMINE, RIBOFLAVIN, AND NIACIN IN MILLED RICE,* CONVERTED VERSUS RAW (1942)

Products	Variety and mill lot											
	Rexoro lot C						Rexoro lot D					
	Thiamine		Riboflavin		Niacin		Thiamine		Riboflavin		Niacin	
	Converted	Raw	Converted	Raw	Converted	Raw	Converted	Raw	Converted	Raw	Converted	Raw
	μg/g	μg/g	μg/g	μg/g	μg/g	μg/g	μg/g	μg/g	μg/g	μg/g	μg/g	μg/g
Rough	3.40	3.40	.55	.55	54.12	54.12	3.12	3.12	.54	.53	54.12	53.72
White milled	2.50	.50	.38	.19	32.17	16.40	2.70	.40	.33	.15	44.95	20.15
Brokens and chips	2.64	.86	.35	.15	40.70	16.07	2.60	.90	.39	.22	39.71	20.12
Bran	6,82	21.05	1.90	2.79	233.52	269.21	7.72	20.15	1.01	2.41	177.12	231.52
Hulls	1.81	2.41	.47	.62	27.92	48.52	1.18	2.42	.66	.81	28.62	39.42

* Samples obtained from pilot plant through the courtesy of the James and Harwell Company (now Mars and Harwell Company), manufacturers of Converted Rice Houston, Texas.

TABLE 24

DISTRIBUTION OF THIAMINE, RIBOFLAVIN, AND NIACIN IN PRODUCTS OF COMMERCIAL MILLING OF CONVERTED RICE* (1943)

Products	Variety and mill lot											
	Nira 301			Rexoro 303			Rexoro 304			Rexoro 305		
	Thiamine	Riboflavin	Niacin	Thiamine	Riboflavin	Niacin	Thiamine	Riboflavin	Niacin	Thiamine	Riboflavin	Niacin
	μg/g	μg/g	μg/g	μg/g	μg/g	μg/g	μg/g	μg/g	μg/g	μg/g	μg/g	μg/g
Paddy or rough rice	3.82	.67	57.43	2.90	.63	52.14	2.81	.70	60.00	3.67	.57	55.8
From milling process:												
Whole brown rice	3.64	.56	57.12	3.00	.57	53.91	2.88	.57	55.21	3.58	.55	50.4
First break huller rice	3.40	.48	46.26	2.90	.44	44.91	2.66	.43	46.09	3.39	.40	43.0
Second break huller rice	3.20	.43	45.21	2.80	.42	42.82	2.53	.41	44.18	3.21	.37	41.0
Third break huller rice	3.18	.40	42.07	2.58	.41	40.13	2.50	.40	42.01	3.20	.35	40.0
Screenings	3.61	.52	46.01	2.81	.51	43.91	2.56	.47	49.21	3.41	.47	47.9
Rice by-products:												
Hulls	1.90	.64	36.51	1.92	.60	30.66	2.22	.70	36.20	2.00	.56	34.0
First break bran	4.70	1.52	203.11	6.80	2.34	154.92	7.00	1.59	176.71	7.30	2.05	197.12
Second break bran	3.86	1.40	170.05	6.33	2.09	151.71	6.09	1.52	161.43	7.00	1.52	185.72
Third break bran	3.64	1.33	163.92	5.62	1.90	140.62	5.86	1.41	152.51	6.36	1.41	180.69

* Samples obtained from manufacturing plant through the courtesy of the James and Harwell Company (now Mars and Harwell Company) manufacturers of Converted Rice, Houston, Texas.

TABLE 25

PERCENTAGE RETENTION OF THIAMINE, RIBOFLAVIN, AND NIACIN IN CONVERTED RICE[a] BEFORE AND AFTER MILLING

Batch number	Type of rice	Thiamine		Riboflavin		Niacin	
		µg/g	Retention[b] percent	µg/g	Retention[b] percent	µg/g	Retention[b] percent
714	rough..........	3.20		.51		53.14	
714	milled.........	2.86	89.69	.38	74.51	42.80	80.54
713	rough..........	3.20		.51		58.10	
713	milled.........	3.00	93.75	.46	90.19	44.30	76.24
551	rough..........	3.00		.73		55.40	
551	milled.........	2.80	93.33	.50	68.49	45.71	80.70
543	rough..........	3.80		.56		60.51	
543	milled.........	3.40	89.47	.46	82.14	44.53	73.59
566	rough..........	3.00		.66		60.02	
566	milled.........	2.86	95.33	.51	77.27	42.11	70.00
544	rough..........	3.70		.52		54.24	
544	milled.........	3.50	94.60	.38	73.08	42.57	78.48
581	rough..........	3.82		.56		60.03	
581	milled.........	3.50	91.62	.41	73.40	49.78	82.92
540	rough..........	3.62		.61		56.63	
540	milled.........	3.25	89.77	.38	63.20	41.21	72.77
556	rough..........	2.87		.51		59.46	
556	milled.........	2.75	95.82	.41	80.40	47.14	79.28
565	rough..........	2.89		.61		51.32	
565	milled.........	2.70	94.07	.38	62.30	49.51	96.47
564	rough..........	3.25		.53		56.56	
564	milled.........	3.06	94.15	.41	77.36	47.46	83.91
711	rough..........	3.00		.63		59.00	
711	milled.........	2.71	90.33	.38	60.32	42.75	72.46
704	rough..........	3.10		.76		60.92	
704	milled.........	3.00	96.77	.51	76.10	49.75	81.66
710	rough..........	3.40		.70		56.41	
710	milled.........	3.20	94.11	.53	75.71	43.29	76.74
708	rough..........	3.24		.78		59.24	
708	milled.........	3.00	92.60	.46	58.97	42.18	71.21
707	rough..........	3.45		.71		60.00	
707	milled.....	3.09	89.53	.51	71.83	48.12	80.20

TABLE 25—Continued

Batch number	Type of rice	Thiamine		Riboflavin		Niacin	
		µg/g	Retention[b] percent	µg/g	Retention[b] percent	µg/g	Retention[b] percent
709	rough..........	3.13		.66		52.50	
709	milled.........	3.00	95.84	.43	65.15	42.27	80.51
712	rough..........	3.30		.46		56.64	
712	milled.........	3.08	93.33	.28	60.87	40.41	71.34
706	rough..........	3.00		.76		60.91	
706	milled.........	2.86	95.33	.38	50.00	49.25	80.85
700	rough..........	3.25		.61		62.50	
700	milled.........	2.91	89.53	.46	75.41	46.14	73.82
699	rough..........	3.25		.61		66.32	
699	milled.........	2.97	91.38	.43	70.50	44.18	66.61
705	rough..........	3.20		.71		65.42	
705	milled.........	2.89	90.31	.48	67.60	50.70	77.50
703	rough..........	3.25		.61		65.00	
703	milled.........	3.00	92.30	.51	83.60	48.30	74.31
702	rough..........	3.37		.61		62.42	
702	milled.........	3.00	90.00	.33	54.10	44.95	72.01
701	rough..........	3.00		.51		54.32	
701	milled.........	2.80	93.33	.40	78.43	47.07	86.55
Average		3.25 3.00	92.25[b]	0.61 0.43	70.82[b]	58.70 45.50	77.62[b]

[a] Obtained through the courtesy of the James and Harwell Company, (now Mars and Harwell) manufacturers of Converted Rice, Houston, Texas.

[b] The meaning of retention is explained on page 67.

All samples are Rexoro, except batch numbers 543, 544, 581, and 540, which are Nira.

The machine automatically stops at the end of the operation (after about 4 minutes); the sample is then removed, whole kernels and broken kernels are separated and counted, and the percent of brokens, whole grains, and total recovery determined.

These data are interpreted into mill results by official conversion factors. The results are given in Table 26 and it was found that the average percent of broken kernels for the 13 samples of converted rice was 3.5 percent compared to 19.5 percent for the samples of raw rice, or by varieties: Rexoro broken kernels, raw 17.4 percent, converted 3.5 percent; Nira broken kernels, raw 23 percent, converted 3.5 percent. The reduced breakage in the converted rice is most probably due to toughening of the grain by the heat treatment or steaming. Our results clearly tend to substantiate the claims of the proponents of rice conversion that the extra costs of converting the rice will be largely offset in extensive commercial practice by the greater yield of head rice in the milled state and are consistent with the findings of Jones and Taylor regarding parboiled rice.[46] Broken grains always sell at a large discount and breakage is therefore an economic factor of first importance to the miller.

TABLE 26

EFFECT OF CONVERSION ON BREAKAGE IN SHELLING

Batch number	Variety	Treatment	Whole kernels	Broken kernels	Yield head rice	Total Yield
			percent	percent	pounds	pounds
304	Rexoro.........	raw.........	61.0	13.5	82.4	108.0
304	Rexoro.........	converted....	72.5	4.0	97.8	110.0
301	Nira...........	raw.........	47.0	21.5	69.5	103.0
301	Nira...........	converted....	71.0	2.5	95.8	107.0
303	Rexoro.........	raw.........	60.5	15.0	81.6	108.0
303	Rexoro.........	converted....	73.0	4.5	98.5	111.0
305	Rexoro.........	raw.........	61.5	12.0	83.0	107.0
305	Rexoro.........	converted....	70.5	4.0	95.1	108.0
543	Nira...........	raw.........	58.5	19.0	80.1	111.6
543	Nira...........	converted....	72.0	3.5	97.2	108.7
544	Nira...........	raw.........	47.5	29.5	70.3	111.6
544	Nira...........	converted....	72.5	5.0	97.8	111.6
540	Nira...........	raw.........	54.0	22.0	76.1	110.2
540	Nira...........	converted....	73.0	3.5	98.5	110.2
581	Nira...........	raw.........	54.5	22.0	76.8	110.2
581	Nira...........	converted....	75.5	3.0	101.9	113.1
566	Rexoro.........	raw.........	43.0	35.0	65.3	113.1
566	Rexoro.........	converted....	74.5	3.0	100.5	111.6
699	Rexoro.........	raw.........	63.5	15.0	85.7	113.1
699	Rexoro.........	converted....	75.5	3.0	101.9	113.1
706	Rexoro.........	raw.........	67.0	13.0	90.4	116.0
706	Rexoro.........	converted....	76.0	3.5	102.6	114.5
704	Rexoro.........	raw.........	64.5	16.5	87.0	117.4
704	Rexoro.........	converted....	75.5	3.5	101.9	114.5
702	Rexoro.........	raw.........	59.0	19.0	80.2	113.1
702	Rexoro.........	converted....	77.0	3.0	103.9	116.0

---

[46] Jones, J. W., and Taylor, J. W. Effect of parboiling rough rice on milling quality. U. S. Dept. of Agric. Circular 340, February 1935.

Malek Process

In this process [47] rough rice or paddy is soaked in water at a temperature of approximately 100°F. for a period of four to six hours, steamed for about 15 minutes at 15 pounds pressure, dried, and milled. The milled parboiled rice may be packed in bulk for home cooking. However, the inventor proposed to can it in vacuum sealed tins and sell it as canned Malek cooked rice. The inventor, Yonan-Malek, is a Persian American.

As the process is not in commercial operation, only two samples have been available to us. On analysis, the following values (expressed as micrograms per gram) were obtained in the milled, parboiled rice:

Thiamine	2.00 μg
Riboflavin	0.40 μg
Niacin	44.0 μg

Lower values were obtained in the canned Malek cooked rice, indicating losses due to faulty handling during cooking:

Thiamine	0.60 μg
Riboflavin	0.30 μg
Niacin	30.0 μg

Through the kindness of Major Virgil O. Wodicka and First Lieutenant Robert R. Mickus of the Quartermaster Corps Subsistence Research and Development Laboratory, Chicago, we are able to present the gist of their views with regard to converted and Malekized rice. From their standpoint, the greater tendency of these processed rices to remain as discrete grains in the cooked state is a great advantage, especially in canned combinations of meat and rice for army rations. Major Wodicka and Lt. Mickus also confirm the greater resistance of the translucent grains to attack by weevils. If the grains are in part chalky rather than translucent in appearance the chalky parts are preferentially attacked by weevils. This condition is much more prevalent in the samples of Malekized rice so far examined. More extended tests of liability to weevil attack are in progress. In agreement with our analyses, the Quartermaster's experience is that the content of water-soluble nutrients in processed rice is materially higher than in white rice but somewhat less than in brown rice.

ARTIFICIAL ENRICHMENT OF RICE

The artificial enrichment of rice has not been considered officially by the Food and Nutrition Board of the National Research Council, nor has the Federal Security Agency proposed hearings on this subject. Indeed, the total amount of experimentation on the artificial enrichment of rice so far made public is scarcely sufficient to permit such consideration. However, looking forward to the time when this topic may come up for discussion in the United States, and also in view of the great need for some systematic attack upon the beriberi problem in the Orient, it is appropriate to consider the possibility of this form of remedy for the deficiencies of white rice.

---

[47] U. S. Patent 2,334,665, Nov. 16, 1943, and U. S. Patent 2,334,666, Nov. 16, 1943, to Milton Yonan-Malek.

In areas where rice is a staple food, it would appear to be consistent with the general policy of the Food and Nutrition Board, as set forth in its resolution of October 1, 1941, to consider artificial enrichment of rice if such local action should prove to be feasible. The problem of artificial enrichment of rice is, however, much more difficult than the artificial enrichment of flour, in view of the necessity of impregnating the entire grain with the nutrients to avoid their loss during rinsing preparatory to cooking. Some rice superficially fortified by a spray of vitamin solution on the surfaces of the grains has appeared on the market but cannot be considered as effectively enriched.

Two methods of internal enrichment of rice have been reported. They are based on the addition of nutrients to any desired level called for by public health consideration, e. g. that found in the natural product, brown rice. In both methods the enrichment is performed in two steps by (a) producing a fortified premix, and (b) diluting the premix with ordinary white rice in a subsequent process.

The production of the premix by the first method [48] "consists in impregnating white rice kernels with a concentrated solution of the vitamins and/or minerals selected for the enrichment, followed by coating of the fortified rice grains with film-forming edible substances. This coat protects the vitamins against deterioration and prevents substantial losses of vitamins during the customary washing prior to cooking.

"The blending of premix with white rice in the rice mills results in the final market form of enriched rice. Neither the premix nor the enriched rice differs in appearance from ordinary polished white rice if thiamine, niacin, and iron in the form of pyrophosphate are used for the fortification, whereas addition of riboflavin of course changes the color of the premix sufficiently to make it visible in the blend.

"A fortification of the premix rice with 1 mg. of thiamine and 13 mg. of niacin per gram and the use of 1 part of premix to 200 of white rice yields a final product with the vitamin content of high quality brown rice. Enriched rice prepared on this basis contains 5 mg. thiamine and 65 mg. niacin per kg. (2.27 mg. thiamine, 29.5 mg. niacin per lb.). The cost of the two vitamins, the coating ingredients, the manufacturing of the premix, and the blending for this degree of fortification is estimated not to exceed 0.25¢ per kg. or 0.114¢ per lb. enriched rice.

"It has been determined that the premix is homogeneously distributed throughout the finished enriched rice. Usual household washing of enriched rice prior to cooking will not remove more than 3 to 5 percent of the incorporated vitamins. Flavor and cooking quality are not affected by this fortification procedure."

It is claimed that storage of premix rice for one year at room temperature did not affect the potency of the thiamine and niacin incorporated. During

---

[48] Developed by Hoffmann-La Roche, Inc., Nutley, N. J. Credit is due Dr. M. F. Furter, Director, Pharmaceutical and Control Dept., for this personal communication. (Patent applications pending.)

Lend-Lease tests, storage for 3 weeks at 45° C., a loss of 3 percent of thiamine and no loss of niacin was found.

The second method[49] of artificial enrichment involves impregnating the white rice grains with a water solution of vitamins (thiamine, niacin, and a highly soluble salt, primary sodium phosphate). The rice is dried and coated with a thin collodion membrane. The vitamins are now protected from rinsing losses but are available to the body in the cooked product, since the film is removed by the hot water. The rice is prepared with a high vitamin concentration and then diluted with unenriched white rice 1 : 100. The rinsing losses are reduced.

The author states: "The principle of the method is the use of a vitamin solution of sufficiently high osmotic pressure to counteract the imbition pressure of the rice grain so that the solution is absorbed slowly and uniformly by the rice grain. In this way we prevent checking and cracking of the grains of rice.

"The membrane applied is of such a nature as to be a dialysing membrane so that normal washing with water will not destroy the protection, while during the cooking of the rice the swelling of the grains, due to diffusion of water through the membrane, ruptures and destroys the coating and allows the vitamins to diffuse into the water. This allows for more uniform distribution of the vitamins during the cooking operation."

Samples of rice prepared by these methods were received and tested in our laboratory. The results of these tests are given below:

TABLE 27

EFFECT OF COOKING ON THE NUTRIENT CONTENT OF ARTIFICIALLY ENRICHED RICE

Sample	Thiamine µg/g	Loss Percent	Niacin µg/g	Loss Percent	Riboflavin µg/g	Loss Percent
Hoffmann-La Roche						
before cooking	5.44		44.15		2.60	
washed three times [a]	5.01	7.90	40.13	9.10	2.51	3.45
cooked in double boiler [b]	5.27	3.12	43.35	1.81	2.53	2.68
cooked in open vessel [c]	4.66	14.33	36.25	17.90	2.31	11.15
Fieger						
before cooking	4.72		46.00			
washed three times [a]	4.08	13.50	39.50	14.1	.....	.....
cooked in double boiler [b]	4.41	6.40	44.00	4.3	.....	.....
cooked in open vessel [c]	2.40	49.10	29.30	36.30	.....	.....

[a] One cupful of rice is covered with one cupful of water, stirred, and the supernatant liquid discarded. This is repeated twice.

[b] One cupful of rice and three half cups of boiling water are placed in the top of a double boiler cooker. All the water is absorbed in the cooked rice, which is not rinsed afterwards.

[c] One cupful of rice is placed in an open vessel with 10 cupfuls of boiling water, cooked, placed in a colander and drained.

These data show that in the Fieger sample with this type of washing about 14 percent of the vitamins are lost; if the rice is cooked in a large volume of water which is discarded the loss is 49 percent. Considerably smaller losses were found in the Hoffmann-La Roche sample.

---

[49] Developed by Dr. E. A. Fieger, Head, Department of Agricultural and Biochemistry, Louisiana State University, Baton Rouge, La. Credit is due Dr. Fieger for this personal communication.

However, one cannot afford to pay too high a price for the protective coating lest it exceed the cost of the vitamins which it saves. One might consider 1 milligram thiamine per day per capita a reasonable minimum provision for an Asiatic rice supply if utmost economy were necessary. This would correspond roughly to 1 milligram per pound of rice where the rice consumption is high (365 pounds per capita). At the present price in the United States, the cost of thiamine for such fortification would be less than 1.6 cents per 100 pounds of rice, or 5.84 cents per capita per annum. Of the Hoffmann-La Roche cost figure of 0.114 cent per pound above quoted, about half represents the cost of the vitamins; the remainder covers coating ingredients, premix preparation, etc. For the Orient, these accessory costs must be reduced to a minimum. In the enrichment of flour in the United States (a simpler process) accessory costs amount to 40 to 50 percent of the basic ingredient costs. It would seem that eradication of beriberi in the Orient by the use of synthetic thiamine will at best cost 10 cents per capita per annum. This, however, would be a small price to pay for the benefit to be gained.

An economic advantage of such artificial enrichment over any form of parboiling is that only 1 to 2 percent of the rice requires special processing. Where weather conditions permit prompt and satisfactory sun drying of parboiled rice, this should not be costly. However, when artificial drying must be resorted to, either constantly or intermittently with changes of weather, drying costs may equal or exceed the cost of fortifying ingredients. On the other hand, if parboiling saves a large amount of breakage and if under Oriental conditions such breakage results in serious loss of saleability, the advantages may lie with parboiling. The perils of inadequate or improper drying under tropical conditions also need careful evaluation.

RÉSUMÉ

A critical review of the possibilities for the nutritional improvement of milled white rice indicates that such improvement is important for only limited segments of population in the United States, specifically in the Carolinas, Florida, Georgia, and particularly southern Louisiana. It is also important in Puerto Rico.

In the Orient,[50] improvement of white rice is of vital importance for Japan, Southeastern China, Malaya, Siam, Burma, the Netherlands East Indies, and parts of British India. While other serious nutritional faults are prevalent in these areas, the eradication of beriberi alone would be of great value to public health and this appears possible by proper treatment of white rice without awaiting the advent of grossly higher standards of living.

The custom of cooking rice in an excess of water and discarding this water prevails with perhaps half of the population of the Orient. This practice has disastrous consequences nutritionally, well nigh comparable with those of the milling of rice to whiteness. No measure other than re-education in cooking methods will supply an adequate remedy for this defect. In areas where this practice is absent or of limited occurrence, it appears possible to consider practicable measures against beriberi.

---

[50] As we go to press an article appears discussing many aspects of the subject, especially in Hawaii. Miller, C. D., Jour. Amer. Dietetic Assn. 21: 345 (1945).

The possible corrective measures include (1) undermilling of rice, (2) widened use of some form of parboiled rice, (3) artificial enrichment of white rice, and possibly (4) the incorporation of vitamins in the salt supply. Of these , the first is handicapped by the great difficulty of controlling the degree of undermilling and of preventing deterioration in storage. The second is limited principally by a popular distaste for parboiled rice, which, however, does not exist among millions of Asiatics who have long been accustomed to it. The artificial enrichment of rice would perhaps encounter the least popular opposition, since the flavor and appearance of the grain are unaltered. It would also be the most economical as only 1 to 2 percent of the rice would have to be specially processed. It will probably be necessary to produce the necessary vitamins in at least the larger Asiatic countries to avoid unpopular drains on their foreign exchange. Prevention of beriberi by addition of thiamine to salt may be feasible in countries where salt distribution is under rigorous government control. Otherwise there would be far too great an incentive for illicit traffic in unfortified salt, which would be much cheaper than the legitimate fortified article. Further work is needed to render thiamine fully stable in salt. The basic annual cost of eradicating beriberi in the Orient is not greatly in excess of 10 cents per capita.

APPENDIX

At the time of going to press, data are available for loss of thiamine in rice after three months of storage in cotton bags exposed to the air at temperature of 71°-76° F. They are as follows:

TABLE 28

EFFECT OF STORAGE ON THIAMINE IN RICE

Variety and Type of Rice	Thiamine µg/g	Thiamine After 3 Months µg/g	Loss Percent
Fortuna			
Rough	3.07	2.98	2.93
Brown	....	....	......
First break	1.34	1.26	6.00
Second break	1.20	1.08	10.00
White	1.00	0.88	12.00
Zenith			
Rough	3.06	3.03	1.00
Brown	3.31	3.11	6.00
First break	1.34	1.14	14.80
Second break	1.25	1.08	13.60
White	0.77	0.70	9.00
Nira			
Rough	3.70	3.60	2.70
Brown	4.10	3.93	4.14
First break	2.25	2.04	9.33
Second break	1.59	1.42	10.70
White	1.00	0.92	8.00
Prelude			
Rough	3.56	3.48	2.25
Brown	3.84	3.66	4.68
First break	1.40	1.26	10.00
Second break	1.12	1.02	7.14
White	0.84	0.80	4.76

The National Research Council

Membership and Organization.—The National Research Council is a cooperative organization of scientific men of America, including also a representation of men of affairs interested in engineering and industry and in the basic sciences upon which the applications of science depend. Its membership is largely composed of accredited representatives of about eighty-five national scientific and technical societies. Its essential purpose is the promotion of scientific research and of the application and dissemination of scientific knowledge for the benefit of the national strength and well-being.

The Council was esablished at the request of the President of the United States, by the National Academy of Sciences, under its Congressional charter to coordinate the research facilities of the country for work on military problems involving scientific knowledge. In 1918, by Executive Order, it was reorganized as a permanent body for the general encouragement of scientific research.

BULLETIN
of the
NATIONAL RESEARCH COUNCIL
NUMBER 114 SEPTEMBER 1946

PROCEEDINGS OF THE PACIFIC SCIENCE CONFERENCE OF THE NATIONAL RESEARCH COUNCIL

Held at

NATIONAL ACADEMY OF SCIENCES
Washington, D. C.
June 6-8, 1946

PUBLISHED BY THE NATIONAL RESEARCH COUNCIL
NATIONAL ACADEMY OF SCIENCES
WASHINGTON, D. C.

Announcement Concerning Publications

of the

National Research Council

The Proceedings of the National Academy of Sciences

is partly supported by the National Research Council which is represented officially on its Editorial Board and Executive Committee. It is open for the publication of papers to members of the National Research Council on the same terms as to members of the National Academy of Sciences.

Subscription rate for the *Proceedings* is $5 per year. Business address: Home Secretary, National Academy of Sciences, 2101 Constitution Ave., Washington 25, D. C.

The Bulletin of the National Research Council

presents monographs especially prepared by Committees of the Council or directories for general use in science compiled by the Council.

The *Bulletin* is published at irregular intervals. A discount of 20% from the list price of the *Bulletins* will be given to all who subscribe for the Series as issued, direct from the Publication Office. Numbers of the *Bulletin* are sold separately at prices based upon the cost of manufacture.

The Reprint and Circular Series of the National Research Council

renders available for purchase, at prices dependent upon the cost of manufacture, papers published or printed by or for the National Research Council. A discount of 20% from the list price will be given to all who subscribe for the Series as issued, direct from the Publication Office.

Orders for the *Bulletin* or the *Reprints and Circulars* of the National Research Council, accompanied by remittance, should be addressed: Publication Office, National Research Council, 2101 Constitution Ave., Washington 25, D. C.

A list of publications of the National Research Council with prices will be furnished upon request.

BULLETIN
of the
NATIONAL RESEARCH COUNCIL
NUMBER 114 SEPTEMBER 1946

PROCEEDINGS OF THE PACIFIC SCIENCE CONFERENCE OF THE NATIONAL RESEARCH COUNCIL

Held at

NATIONAL ACADEMY OF SCIENCES
Washington, D. C.
June 6-8, 1946

PUBLISHED BY THE NATIONAL RESEARCH COUNCIL
NATIONAL ACADEMY OF SCIENCES
WASHINGTON, D. C.

ACME PRINTING COMPANY
WASHINGTON, D. C.

Objectives of the Conference

To form an effective organization of American scientists interested in the Pacific, to encourage and assist scientific research and activities in the Pacific area, and to further international cooperation along these lines.

TABLE OF CONTENTS

PAGE

OBJECTIVES OF THE CONFERENCE ... iii

GENERAL MAP OF THE PACIFIC ... x

THURSDAY MORNING SESSION

JUNE 6, 1946

Opening Remarks by the Chairman,
Dr. Herbert E. Gregory ... 1

Address of Welcome,
Dr. Frank Jewett ... 1

Address of Welcome,
Dr. Ross G. Harrison ... 2

Objectives of the Conference,
Dr. Douglas L. Oliver ... 5

Statements of Liaison Representatives:

Department of State,
Honorable Abbot Low Moffat ... 8

Navy Department,
Vice Admiral Richard L. Conolly ... 10
Rear Admiral H. G. Bowen ... 11

War Department,
Colonel G. W. Trichel ... 13
Colonel Otis O. Benson ... 14

U. S. Coast Guard,
Commander G. Van A. Graves ... 15

Department of the Interior,
Mr. Eric Beecroft ... 15

PAGE

Department of Agriculture,
Dr. W. V. Lambert 21

Department of Commerce,
Rear Admiral Leo O. Colbert 23

U. S. Public Health Service,
Dr. W. H. Wright 23

Smithsonian Institution,
Dr. Alexander Wetmore 25

Social Science Research Council,
Dr. Robert B. Hall 26

American Council of Learned Societies,
Mr. Mortimer Graves 27

American Council on Education,
Dr. A. J. Brumbaugh 29

Procedure of the Conference,
Dr. George P. Murdock 30

THURSDAY AFTERNOON AND FRIDAY MORNING DIVISIONAL MEETINGS
JUNE 6 AND 7, 1946

Summary 32

FRIDAY AFTERNOON SESSION
JUNE 7, 1946

Summary 33

Proposed Organization of the Pacific Science Survey 33

Specific Recommendations:

Division of Anthropological Sciences 34

Division of Earth Sciences 35

Division of Oceanography and Meteorology 37

PAGE
Division of Plant Sciences 39
Division of Public Health and Medicine 40
Division of Zoological Sciences 40

General Recommendations:

Declassification 42
Conservation 42
Fellowships 42
The Pacific War Memorial Foundation 43
Field Stations 43
Science Appraisal 43
Documentation Centers 44
Internships 44
Pacific Congress 44
Check Lists of Flora and Fauna 44
Descriptive Geography of Micronesia 44
Scientific Appraisal of Bikini 44
Specific Scientific Recommendations 44

Recommendations Pertaining to International Cooperation,

Extension of Act of August 9, 1939 45
Visitors' Facilities 45
Collaboration with the United Nations 45
Liaison Stations 45
Regional Floras 45
Institut Francais d'Oceanie 45

PAGE

Scientific Research Station at Hollandia 45

Algae and Algal Survey of Philippine and Indonesian Waters 46

Standardization of Nomenclature 46

Rehabilitation of Scientific Libraries and Collections 46

Scientific Center in the Philippines 46

SATURDAY MORNING SESSION
JUNE 8, 1946

Opening Remarks by the Chairman,
Mr. Harold J. Coolidge 47

Remarks by Dr. Harold St. John,
University of Hawaii 48

Remarks by Dr. Peter Buck,
Bishop Museum 51

Discussion of Land Field Stations 54

Discussion of Floating Stations 61

Discussion of Acquisition of Surplus Equipment 64

Discussion of Fellowships and Grants-in-Aid 67

General Remarks by Three Divisional Chairmen,

Dr. Herbert E. Gregory,
Division of Earth Sciences 70

Dr. Paul F. Russell,
Division of Public Health and Medicine 71

Dr. Robert Cushman Murphy,
Division of Zoological Sciences 72

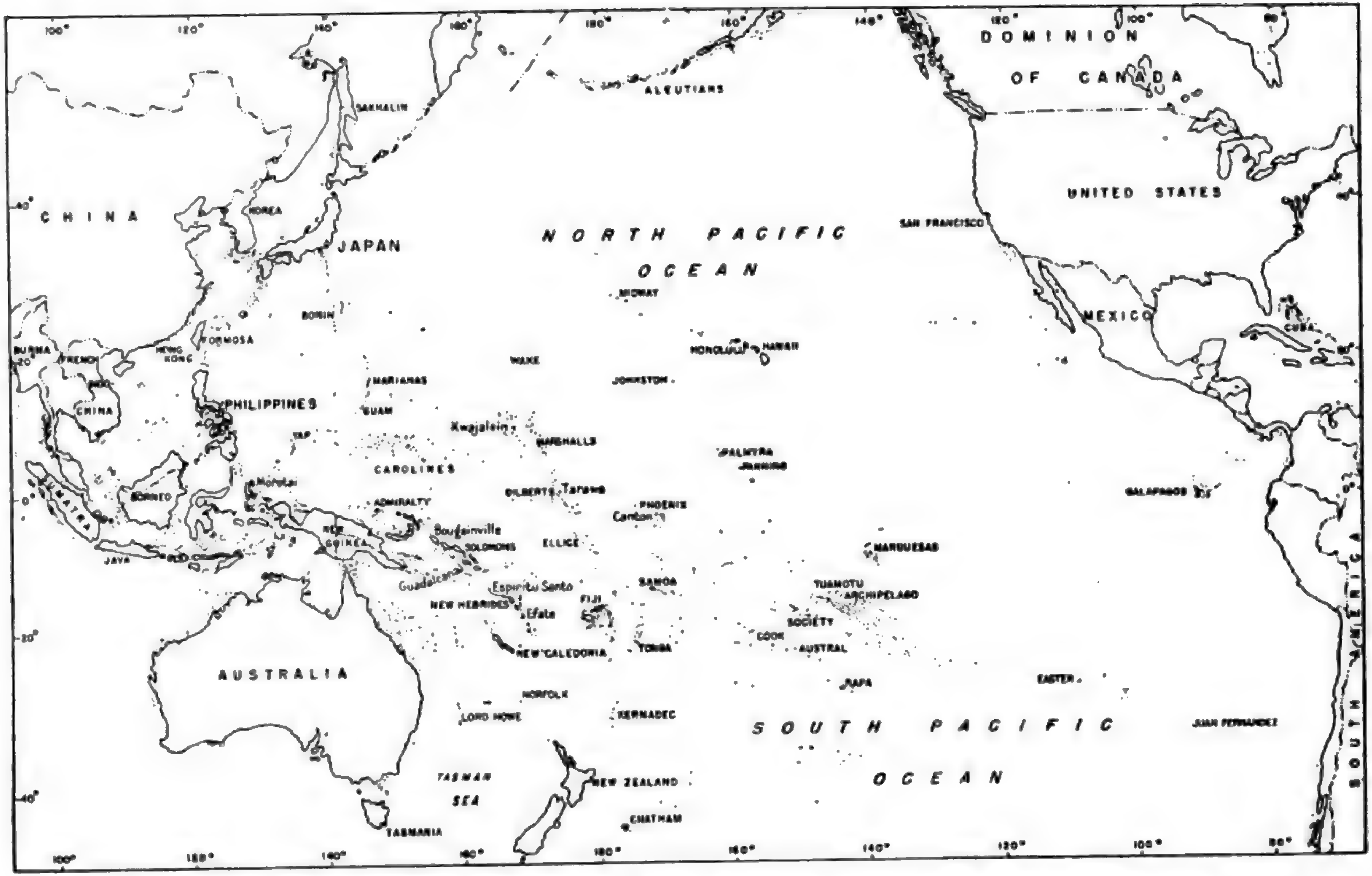
Remarks by the Chairman,
Foreign Cooperation 72

PAGE

Concluding Remarks by Dr. George P. Murdock,
Chairman of the Steering Committee 73

CONTINUATION COMMITTEE MEMBERSHIP 75

CONFERENCE ATTENDANCE 76



General map of the Pacific reprinted from the Geographical Review through the courtesy of the American Geographical Society.

THURSDAY MORNING SESSION

June 6, 1946

Opening Session

The Pacific Science Conference, called by the National Research Council, was held at the National Academy of Sciences, Washington, D. C., June 6-8, 1946. The meeting was convened at 10 a.m., Dr. Herbert E. Gregory, Chairman, Committee on Pacific Investigations, presiding.

Chairman Gregory: We are convened to consider plans, programs and an organization for the development of science in the Pacific area.

To me this meeting seems like coming home. On the attendance list I see the names of twenty-eight men with whom I have been associated in doing Pacific work, but I confess that I miss very much such grand old wheel horses as Wayland Vaughan, Henry Washington, Arthur Day and Clark Wissler from the United States; Hedley, Andrews and Marshall from New Zealand and Australia; and those magnificent men from Japan, Sakari and Shibata.

Also, my mind slips back to the time when we first began to consider the formulation of a program for systematic Pacific work. It was initially considered by the British Association for the Advancement of Science called to meet in 1914 in Sydney. This meeting was interrupted by the war, but interest in the project was carried on by a delegate, William Morris Davis, who organized a symposium on Pacific exploration. The program was more fully developed at the San Francisco Exposition in 1916 and at a conference in Honolulu in 1920 having the same name as this conference.

The first conference was different from this one in two respects. It had an international representation but no money, and but moderate professional backing. However, much work was done between 1920 and 1940, and, of course, during the war research was intensified, with unlimited funds and an unlimited number of men interested both in military and in civilian applications of science. You might say that Pacific exploration and study have become a passion among our scientific groups—a passion that has led to the present meeting.

Throughout all those years, the National Academy of Sciences and the National Research Council have been guiding and supporting the Pacific sciences in every way possible. It is a pleasure indeed to introduce Dr. Frank B. Jewett, President of the National Academy of Sciences, and to hear what he has to say and whatever advice he wishes to give us.

Dr. Frank B. Jewett (President, National Academy of Sciences): Dr. Gregory and Members of the Conference: My part in this conference is to be a very short one, merely a word of welcome to you. As President of the National Academy of Sciences and on its behalf and on behalf of the National Research Council, which is its principal operating agency, I desire simply to welcome you here and to assure you that anything which either the Academy or the Research Council can do to further the objectives which you gentlemen have in mind, you may be assured we will endeavor to do.

The only addition I might make to a word of welcome is to recall to your minds the functions of the Academy and the Research Council.

The Academy was originally set up by Congress more than eighty years ago to be the official adviser to Government in matters of science, to provide machinery which would assure to Government at all times the best that American science and technology had to give, and to provide a completely unbiased and uninfluenced source of information whenever needed by Government. That was the basis on which the Academy was incorporated by Congress in 1863, and it served until the time of World War I substantially as it was intended, that is, wholly as an Academy.

When World War I came, it became apparent that American science and technology had grown to such an extent that a body the size of the Academy was no longer sufficient to cope with the multifarious problems of modern warfare. At the request of the President of the United States, the Academy therefore enlarged its base by the creation under its Charter of a National Research Council, which acted temporarily in World War I much as the Office of Scientific Research and Development has operated in this war, as an *ad hoc* agency.

The work of this temporary National Research Council was so successfully carried out during the war that the President in 1918, by an Executive Order, officially asked the Academy to perpetuate the National Research Council, not only to supplement and strengthen the Academy in its advice to Government, but to do more than that, to assist American science and technology in all fields—civil as well as military—to a full fruition of the nation's capacities. Since that time, the Research Council has operated as a permanent agency of the Academy to do all the things that can be done by an organization which is really the focus of American science and technology.

It is an organization unique in the world in that it provides a mechanism for bringing together in a common place, and without elaborate, rigid machinery, those who have access to everything which might be pertinent to the solution of any problem which is of interest to civil or military technology. The type of conference in which you are here assembled is a good example of the kind of thing that the Research Council can do to be of service in the solution of problems, in that it provides a common meeting place for persons of divergent points of view, all interested in some single objective, and at the same time provides the basis for machinery which can assist in carrying out their recommendations.

So it is with a great deal of pleasure that, on behalf both of the Academy and of the Research Council, I welcome you here. From past experience and from what has been done in this same general sector in years gone by, I am quite sure that as a result of your meetings during the next two or three days, something of really great benefit to science, to the nation, and to the world will be evolved.

CHAIRMAN GREGORY: For the National Research Council, its Chairman, Dr. Ross G. Harrison, will speak. Dr. Harrison served as President of the Sixth Pacific Congress, and everybody agrees that it was tops. He is remembered all through the Pacific.

DR. ROSS G. HARRISON (Chairman, National Research Council): Mr. Chairman, Ladies and Gentlemen: It is a pleasure for me to join with Dr. Jewett in welcoming you here today. The large attendance is evidence of the great interest in the subject of the conference. When it was first planned, we thought that perhaps thirty or forty might come and that that number would afford representation to all groups interested, but now there are three or four times that many present, and it has been necessary, much to our regret, to disappoint many who would have liked to attend.

For many years the Research Council has had an active interest in the Pacific. It began to take form, as Dr. Gregory has already stated, during World War I, when the National Academy of Sciences held a symposium on Pacific exploration, which was arranged by the late Professor W. M. Davis. At that time a Committee on Pacific Exploration was set up in the Academy, and at the close of the war it was transferred to the National Research Council and later was termed the Committee on Pacific Investigations. This Committee is still in existence.

The magnitude of the area of the Pacific and the problems involved made it evident that their advancement would require an international organization. This led to the First Pacific Science Congress, held in Honolulu in 1920, in which our present Chairman, Dr. Gregory, was one of the leading spirits. Six of these congresses have been held. Besides the one in Hawaii, there have been meetings in Australia, Japan, the Dutch East Indies, Canada, and the United States, the last in 1939 in California. The Seventh Congress was scheduled for 1943 in Manila, but it will still be several years before it can be held. In these congresses the National Research Council has served as the adhering body for the United States. It had the responsibility of organizing the Sixth Congress.

Along with this international organization, the Research Council has continued to maintain its interest in the Pacific through its Pacific Investigations Committee and through several committees cooperating with it, each devoted to a special field, such as oceanography, land classification and utilization, and seismology. During the war a great deal of research was done in the Pacific, but it was related to the conduct of the war and was practically all secret. Since the close of the war, the general interest in the Pacific has grown immensely, and opportunities are opening up for study of areas that for many years during Japanese occupation were inaccessible to scientists from other countries.

As early as last autumn the National Research Council began to get suggestions and questions regarding the reopening of activities in this field. It developed that there were a number of independent groups and individuals interested, some of which I may mention: Dr. Douglas Oliver, who prepared a memorandum entitled, "A Plan to Explore Former Japanese Mandated Islands"; parties from the Bishop Museum and the University of Hawaii, that have already begun field work in Micronesia; a group interested principally in fishery problems; a group, centering in New York, acting upon a proposal of Colonel Archibald Roosevelt that there be established a Pacific Foundation as a war memorial. This appeals to me as an excellent suggestion.

The time was opportune for bringing these different groups together and, accordingly, a small preliminary conference was held here on April 4, at which plans were initiated looking forward to the present conference. It was realized from the beginning that many Government departments and agencies were interested in the Pacific, and steps were taken to insure that these departments and agencies would be represented in the conference. I am happy to say that many such representatives are here with us today.

Now that you are all assembled, I should like to say a word regarding the National Research Council, repeating perhaps some of the things that Dr. Jewett has already said, but I feel that we must not fail to make clear what the National Research Council stands for.

The Council is an agency of the National Academy of Sciences. The Academy was founded during the Civil War. It is a learned society which is charged by its congressional charter with the public duty of advising the government on scientific and technological matters whenever called upon. The Council has a broader mandate, as expressed in the Executive Order of President Wilson: In general, to stimulate research in the mathematical, physical, and biological sciences; to formulate comprehensive projects of research; and to promote active cooperation in research. The actual order is more detailed, but that is the essence of it.

The Council is made up of its officers, elected members, representatives of constituent scientific societies, eighty to ninety in number, including all of the more important ones, and representatives of Government departments and independent agencies designated by the President of the United States on the nomination of the National Academy of Sciences.

The Council is not a Government agency and receives no financial support from the Government, but it is charged through the Academy's Charter with the duty of serving the Government in an advisory capacity.

The fields of interest of the National Research Council are the natural sciences and technology. It does not concern itself with the social sciences or the humanities, except in so far as natural science may impinge upon these areas, and it does not consider itself competent in them. Recognizing, however, that many scientific and technical problems have social implications and that there are many common interests, the National Research Council, the Social Science Research Council, the American Council of Learned Societies, and the American Council on Education have formed an organization for dealing with such problems of common interest as may arise.

I wish to assure you, however, especially those who have expressed some uncertainty regarding the implications of the present conference and the activities of any permanent organization that may arise from it, that the National Research Council will confine itself wholly within its sphere of competence and will not attempt in any way to concern itself with things that might be regarded as political or purely administrative.

There are two main directions in which the Council may be useful in connection with this project: First, in exploring possibilities of research and promoting those projects that seem promising. Second, in advising Government agencies that are charged with the administration of our possessions in the Pacific on matters in which scientific men are competent.

This is all I need say. In turning the conference over to its more serious deliberations, let me express the wish that it will be fertile in ideas and that these may lead to substantial practical undertakings.

CHAIRMAN GREGORY: Many a Pacific conference had a committee on permanent organization, or projected organization, or desirable organization, but no definite plans were made because the feeling that an organization was not wanted was too strong; but obviously we are past that stage, and among the men who have helped to clarify this situation is Douglas Oliver, who will present his view of the objectives of this proposed Pacific Science Survey.

Dr. Douglas L. Oliver (U. S. Commercial Company): Mr. Chairman, Ladies and Gentlemen: The general objectives of this conference are stated in the printed program. I have been asked to make these objectives more explicit in terms of the needs for coordinated research, in terms of the nature of a proposed organization to implement research, and in terms of the functions of such an organization. These proposals are tentative. It is hoped and expected that the conference will supplement them and revise them and present to the National Research Council a truly representative set of recommendations.

Most of us can enumerate the needs for such a program in terms of our own personal experiences. I invite you to recall yours while I relate some of mine.

My experience in Pacific science began in 1935, when my university invited me to participate in an anthropological expedition to Melanesia. Having specialized, as both graduate and undergraduate, in the ethnology of Africa, I was of course a logical choice. It is funny enough now, but it was no laughing matter then to try to learn what others had done or were doing or what line my own investigations should follow in a field so vast and complex as Melanesia. The slightly less than princely salary I was getting didn't enable me to supplement local facilities by traveling to other institutions for collections and expert advice. And there was no central index to which I could turn, no single source of information on what field projects I should undertake. Therefore, I moled along in library stacks for a year before I dared to leave for the field.

Equipment was another problem. What were field conditions like? What facilities were obtainable in the field? Lacking a specific objective and ignorant of local circumstances I was unable to equip myself realistically, but I had to do something. So, up went the cost and the baggage weight.

Official clearances themselves required almost ambassadorial action, but after some months they were secured, so off I went.

Then there followed weeks on the water to Australia, weeks waiting for an island steamer, weeks traveling to Rabaul, where an almost complete refitting was necessitated by local conditions. At long last field work began, just twenty-four months after I accepted the commission.

It was a preposterous waste of time, energy, and materials, but many of you can recall experiences just as bad. Such experiences point up the need for facilities which will free the individual scientist from having to become bibliographer, travel agent, and supply officer, and enable him to apply his knowledge and techniques effectively and continuously to actual field research.

Another personal experience with a bearing on this subject developed in connection with war work. Like so many of us with field experience in the Pacific, I was assigned to a war agency and directed to collect data and compile reports on Pacific islands. There was no central body to which harassed administrators could turn for complete coverage on that part of the world. So, taking no chances, most agencies frantically set out from scratch to do the whole job. We all remember the duplication, confusion, and expense involved; even worse was the waste of precious time. Attempts—some of them partially successful, like the Ethnogeographic Board—were eventually made to consolidate resources, but these never fully satisfied many of us who hoped to see organized an authoritative and responsible body for Pacific area scientists to which Government could turn for advice and assistance in time of war or peace.

This hope has become even more fervent since I have myself become a more or less harassed Government administrator. Assisting the Navy with the rehabilitation of native trade and industry in Micronesia, I came to know how useful and economical it would be to be able to turn to a panel of scientific experts for assistance.

Some day, when the national emergency has passed, I want to return to the field again on a research project, but next time I can't spend two years or even four months on preliminaries. I shall want to know what anthropological project requires priority attention, and I shall want to get to the spot quickly and waste no time in carrying out my work and I shall want to make the product of my researches promptly available to interested individuals or institutions.

To me, therefore, the need for an organized program of Pacific research is very real and very personal, but there are other less personal needs that are impelling.

There is, for example, the purely scientific need. Not one of our disciplines can claim to have complete coverage on Pacific islands; many fields are literally untouched.

Then, there is a need for data which can be applied to the solution of practical problems. These range all the way from problems on climatic conditions and marine fauna to considerations of ethnic peculiarities.

Third, in order to save our energies and to work effectively, there is the practical need for coordinating our efforts with the administrative policies and procedures of governments ruling in the area. But in this connection certain points should be made clear: as scientists, we object emphatically to any attempt to exercise arbitrary control over our research. Of course, we have no proper concern with the ultimate disposition of the Pacific islands wrested from Japan, nor with the distribution of administrative responsibilities among agencies of the United States Government as they may be worked out in the future. We should be prepared to accept authoritative decisions on these matters and to adjust our organization and program in accordance with them. In so doing, however, we should be careful to preserve our scientific tradition of independence of arbitrary political controls.

Last, there is the instrumental need for securing facilities to enable us to get to the field quickly and to conduct our investigations efficiently and without undue hardships.

Two factors make 1946 a particularly appropriate year in which to undertake an organized research program. First, our country's interest in the Pacific has suddenly grown from apathy to intelligent concern. A few years ago, when I returned from New Guinea, acquaintances greeted this fact with, "Oh, yes, New Guinea. I have always wanted to cruise in the Caribbean, too!" But today they want to know whether I was at Salamaua, Hollandia, or Milne Bay.

A second factor is the circumstance that the iron curtain that concealed the Japanese-mandated archipelagoes has suddenly been lifted, and science is presented with a challenging new opportunity.

Granted, then, that there are genuine needs for a coordinated program, what can be said about the nature of an organization appropriate to implement such a program?

First of all, participation should be nation-wide. My West Coast and Honolulu colleagues will, I feel certain, not wish to claim exclusive prerogatives simply because of their relative nearness to the area.

Second, the organization should neither in fact nor by implication constitute a monopoly, nor should it seek to regiment scientific effort. It is earnestly hoped and may be reasonably expected that most scientists wishing to work in the Pacific will be glad to affiliate with the proposed organization and receive the benefits of improved facilities for research. However, there may be individual scientists who, although qualified and serious-minded, nevertheless wish to work outside the organization, and this conference should do nothing which might be construed as affecting the freedom of action of such individuals.

Third, the organization should serve as a clearing house, utilizing and coordinating existing facilities, rather than attempting to create an independent institution.

Now to turn from generalities about the nature of the proposed organization to certain specific functions which it might usefully perform, it seems to me that there are three classes of such functions: first, the formulation of a coordinated research program; second, assistance in implementation of projects; and, third, dissemination of the results of research.

With respect first to formulation of a coordinated research program, it should be up to each division to appraise the current status of knowledge about its particular field, and to define specific research projects for immediate and future investigation. Special attention should be devoted to utilizing the rich materials compiled by federal departments and agences during the war and the quantities of new source material recently acquired in Japan.

The second function, that of providing practical assistance for research, should be implemented by helping to get the scientist to and from the field and by providing him with facilities while he is there. Getting the scientist to the field consists of helping him to secure passports and visas, supplying him with transportation aid, and briefing him with realistic advice on current field conditions.

Providing the scientist with facilities in the field is a topic that deserves the serious consideration of this conference. Thought should be given to setting up centers in Hawaii and Guam where scientists may store their gear, deposit their notes and collections for safekeeping or preparation for shipping, where they themselves may stay and work and where they may turn for assistance in arranging transportation. Honolulu, with such rich resources as those of the Bishop Museum and the University of Hawaii, is particularly appropriate as a point of departure for the field. And Guam is now the administrative and communications center for all Micronesia.

Consideration should also be given to setting up field stations in other parts of the Pacific under U. S. administration, and to securing vessels and vehicles for use around those stations. Also, many of us would like to see this conference encourage plans for cooperating with other nations in setting up field research centers in such places as Tahiti, Samoa, New Caledonia and New Guinea, and in rehabilitating facilities that existed before the war in Indonesia and the Philippines. One important by-product will surely develop from this program. We shall be happier and more effective in our own work if we learn to work together in this common enterprise, and we shall unquestionably strengthen friendships with colleagues from other nations in the Pacific.

In this connection it is pertinent to call attention to a recent regulation of the State Department regarding disposal of U. S.-owned foreign surplus property: "Surplus property may be exchanged for other property, real or personal, tangible or intangible, where this course of action is determined by the Department of State to be in the best interest of the Government of the United States." (Departmental Regulation 108.5, part of Section (e)(3)).

It would seem obvious that tangible or intangible property consisting of scientific data gathered in the Pacific would contribute to the interests of the United States Government and, therefore, that the proposed Pacific science organization should be entitled to receive surplus property useful to scientific research.

Another important role which a Pacific science organization could play would consist in securing fellowships and other financial assistance for scientists who represent institutions with limited budgets.

The third function of the proposed organization would be to help disseminate the results of research. No scientific study has really been completed until its results have been made generally available. It is suggested for your consideration that the proposed organization will assume as one of its prime responsibilities the prompt publication or dissemination of the results of research which it sponsors.

In conclusion, it would seem obvious that the key to success of a Pacific science survey lies in the establishment of an active, liberally financed secretariat in the National Research Council, to serve as a focal point for implementing the recommendations of this conference.

CHAIRMAN GREGORY: Representing the Department of State the Honorable Abbot Low Moffat, Chief, Division of Southeast Asian Affairs.

HONORABLE ABBOT LOW MOFFAT (Chief, Division of Southeast Asian Affairs, Department of State): Mr. Chairman, the Department of State welcomes the opportunity afforded by the National Research Council to participate in this conference for the encouragement and development of scientific research in the Pacific. There is no need to list the many phases of our relations with other countries in which knowledge can be obtained only by scientific research and in which that knowledge is playing an increasingly essential role. The Department is conscious of that role and within its sphere of activities is lending a helping hand where it can.

The exchange of research scholars through its program of cultural cooperation with other countries is one general example.

A recent and more specific example will be of especial interest to the conference. As most of you doubtless know, the French Government has created l'Institut Francais d'Oceanie to be established at Noumea. Certain practical difficulties were encountered, but, fortunately, in connection with the financial agreement concluded between this Government and the French Government a few days ago, it was found possible to provide for the transfer to the French Government of certain surplus Army and Navy property and installations for the use of the Institute With this timely assistance, it is hoped that this new organization for scientific research in the Pacific will shortly be able to commence its work.

An opportunity is now presented to scientists to undertake research in those islands of the Pacific which for twenty-five years were closed to the outside world by the Japanese.

I was deeply interested in a recent article by Robert von Heine-Geldern in *The American Anthropologist.* (Although I am not a scientist and am in the State Department, I read the article voluntarily before this meeting was called!) That article cited lost opportunities of adding to the world's knowledge because scientific study was not undertaken while facts which might furnish the key to certain problems were still available. We all recognize, I am sure, that the changing conditions in the Pacific islands brought about by the impact of war and the new contacts to which their inhabitants are exposed make it imperative that scientific research, carefully and intelligently planned, should be encouraged, lest once again knowledge be lost by inaction or delay. I assure you that the Department of State is keenly interested in encouraging this research.

In this connection there are certain considerations to which Dr. Oliver has already referred from the scientist's point of view. Although they are obvious, it would be well, because of their bearing on our relations with other countries, that we keep these considerations in mind during the deliberations of the conference.

Knowledge is the heritage of the whole world, and true science does not recognize political boundaries. International cooperation in scientific research and the free exchange of scientific knowledge have always strengthened the scientist and his work. One of the important aims, as stated in the program, in planning of the research with which this conference is concerned, should, I believe, be the encouragement of international cooperation in such research. From the Department's point of view, this is especially important because the Marshalls, the Carolines, and the Marianas Islands have had for the past quarter century and still have an international status.

It would also seem of fundamental importance that, in encouraging scientific research, care should be taken, as Dr. Oliver said, that the planning not step over—and it is an easy step to take unwittingly—from encouragement to control. Any action which might be construed as giving to one group of scientists, or to a special field of science, a monopoly to the exclusion of, or even to the limitation of others would, aside from its very negation of the scientific approach, rightfully, I believe, be subject to serious criticism. For the same reasons, obviously, publication of the results of research should be untrammeled and freely available to all.

It is clear that while the islands of the Pacific are under military government, the planning of research in those areas must be carried on in close cooperation with the appropriate naval and military authorities, and such research must be subject to the necessary limitations imposed for security reasons by those authorities.

I need scarcely remind this gathering, however, that no international settlement has as yet determined the final disposition of those islands, nor has any determination been made as to the form of administration of such of those islands as may be administered in the future by the United States. Accordingly, the Department of State considers it is important in encouraging and planning scientific research in the Pacific islands now under American administration, and especially in the former Japanese-mandated islands, that no definitive action be taken which anticipates or prejudges or which might be construed as anticipating or prejudging the future disposition or administration of any of those islands.

I want to state personally, Mr. Chairman, how happy I am to be here. I hope I shall have the opportunity and the ability to absorb some scientific knowledge at the divisional meetings. For the Department, I want to repeat our appreciation for the opportunity of participating in this conference and our assurance of wholehearted cooperation.

CHAIRMAN GREGORY: Vice Admiral Richard L. Conolly, Deputy Chief of Naval Operations.

VICE ADMIRAL RICHARD L. CONOLLY (Deputy Chief of Naval Operations for Administration, Navy Department): Mr. Chairman, Members of the National Research Council, Fellow Guests: I consider myself doubly fortunate in having the privilege of addressing you at this opening session of the Pacific Science Conference. I am fortunate in being here today when you are discussing and formulating a program of scientific research in the Pacific and fortunate in representing the Navy at a conference which is of immediate concern to the Navy Department.

The Navy Department has a twofold interest in the scientific research in the areas of the Pacific. First, from a purely military standpoint in such fields, among others, as oceanography, meteorology, seismology, zoology, and biology, the knowledge acquired in the course of such research will have a direct bearing upon the planning and conduct of naval operations. Secondly, in view of the Navy's present responsibilities with respect to civil and military government in certain parts of the area, we are vitally concerned in the acquisition of that knowledge pertaining to the peoples governed which will assist in the improvement of their health, economy, and well-being, as well as in the establishment of self-governing communities.

Recognizing the Navy's interest, the Council has kindly suggested the appointment of liaison officers and scientists to the committees dealing in those branches of science in which the Navy is directly or indirectly concerned. These liaison members have been appointed by the Secretary of the Navy.

By reason of its character, the National Research Council is particularly well suited to sponsor a program of the nature of the one which is now proposed.

At the moment, the aftermath of war finds in the areas which were within the field of combat operations a lack of the usual modes of transportation, a lack of port facilities, and congested conditions with respect to housing. Most of the facilities now in existence are those constructed by the armed services in the course of prosecuting the war. Hence, it is natural that institutions and individuals who desire access for scientific purposes to those areas which are presently under Navy control should apply to the Navy Department for assistance in furthering their projects. The National Research Council is the logical agency through which such requests can be channeled to the end that available facilities can be employed to the best advantage and that duplication of effort may be avoided.

Also, as a correlating and coordinating agency, the Council is in a most favorable position to invite participation by well qualified groups and to disseminate the results of surveys in the various fields, not only to those departments of the Government which have an interest therein, but also to those institutions and individuals who desire knowledge for use in their own work.

It is my earnest hope that the program which is now proposed will be pushed to early success.

It is a pleasure to me to be able to state that the Secretary of the Navy has authorized the Chief of Naval Operations to extend to the Council such aid and assistance as may be available in the way of transportation to otherwise inaccessible places, temporary messing and billeting, and such other facilities as may be available and useful to scientific groups visiting the areas now under the control of the Navy.

I assure you that both the Secretary and Admiral Nimitz are sincerely and warmly interested in your work in the Pacific.

CHAIRMAN GREGORY: The United States Navy is also represented by Rear Admiral H. G. Bowen.

REAR ADMIRAL H. G. BOWEN (Chief, Office of Research and Inventions, Navy Department): Mr. Chairman, Mr. President, Members of the National Research Council, and Members of the Pacific Science Conference: I am happy to have this opportunity to summarize for you at the opening session of this conference some of the fields of scientific interest in the Pacific Ocean areas in which the Navy is particularly concerned. All phases of this conference are of interest to the Navy. Indeed, special representatives to each divisional meeting have been appointed. But the brief remarks I shall make now will indicate where the emphasis of our interest lies.

World War II has demonstrated beyond dispute that a first-class Navy cannot exist for long in the so-called atomic age divorced from science and research, either in spirit or in fact. Theories and experiments of a scientific nature, heretofore associated almost exclusively with academic, industrial, or private enterprise, have become of the most urgent interest to the military services. No longer can the Navy, for which I speak, follow science at a casual distance, conservatively selecting from its harvest only the choicest fruits. Time, like distance, has been suddenly telescoped, and if the Navy is to maintain its place in the forefront of the world, it must walk with, not after, science—science wherever it is, in government laboratories, in industry, in universities, or in private institutions.

The interlocking of this endeavor must be firm and mutually beneficial. In order to translate this determination into a positive fact and to seal the relationship between science and the Navy, the Secretary established the Office of Research and Inventions in May, 1945. Since one of the main functions of the Office of Research and Inventions is to coordinate research planning in the Navy, it was considered appropriate that this Office outline for the conference the Navy's interest in future scientific research in the Pacific area. More complete details of the Navy's program will be given later by Navy representatives at the divisional meetings.

In the anthropological sciences, there is a great need for textbooks in the native languages. The inhabitants of many of the Pacific islands have no written language, and in order to govern these islands efficiently, it is necessary that we learn more about their languages, the native socio-political structures, and their native trade.

In the earth sciences, the Navy wants to know more about the structure of atolls, the general character of land formation, harbor and coastal silting, variation of the earth's magnetic field, and geophysical variation of ionization and other electrical properties of upper air affecting radio wave propagation. In general, little is known about tropical oceanography. Some studies required are: distribution of fouling and noise-making organisms; studies of current flow, velocities, directions, and seasonal distribution; characteristics of sea bottom and distribution of chemical properties.

One of the most important considerations in connection with amphibious operations in the Pacific islands was that of the expected surf and swell conditions on the beaches. Accurate forecasts of swell and surf conditions have many peacetime applications, one of which arises from unloading supplies from unprotected anchorages.

We are also concerned with a study of the interrelations of sea and atmosphere. Important studies will include basic theoretical work on the cause and mechanism of fogs and the study of the stability of lower layers of the atmosphere, in part depending on air-sea temperature differences as related to temperature gradients in the upper ocean layers. The bathythermograph program from weather vessels and other ships will supply data for these investigations.

In meteorology, our extensive naval operations in the Pacific brought forth valuable information regarding weather processes. Much remains to be learned about frontal conditions in tropical areas, the interaction of air masses between northern and southern hemispheres, and the direct or indirect effects that these processes may have on weather conditions later experienced in mid-latitudes. Little progress has been made in the development of reliable long-range forecasting.

Research in the plant sciences is desirable in order to gain a better understanding of the distribution and cause of phosphorescent waters, and a knowledge of fouling in strategic areas to determine the maximum depth of significant marine growth.

Basic in any zoological work in the Pacific island waters should be a comprehensive zooplankton investigation carried out periodically throughout the years. It is a key to the natural economy of the area. More can be determined about the composition of the marine population of an area by a systematic plankton analysis than in any other way. For example, a study of this sort would afford the quickest and most effective means of determining what species of sound-producing animals and fouling organisms occur in any particular area, together with an accurate measure of the relative abundance, distribution, and breeding seasons.

The importance of the program which will be formulated in the divisional meetings on public health and medicine cannot be stressed too strongly. The interests of the Navy's Bureau of Medicine and Surgery are broad and are concerned primarily with increasing the knowledge of public health and medical matters peculiar to the natives of the islands and with the problems pertaining to occupying forces, such as epidemic diseases.

In summary, our experience in World War II has shown that the Navy cannot neglect any branch of science. Our Navy must constantly be reinforced and improved in accordance with scientific potentialities. This improvement must grow out of fundamental research which brings new and better solutions to age-old problems. The strength or weakness of this nation to defend itself in the future lies largely in today's explorations on the frontiers of scientific knowledge.

CHAIRMAN GREGORY: Representing the United States Army, Colonel G. W. Trichel, Chief, Research and Development Division, General Staff.

COLONEL G. W. TRICHEL (Chief, Research and Development Division, General Staff, War Department): Mr. Chairman and Members of the Conference: It is a personal pleasure to come here this morning as the representative of the War Department to express to the conference the War Department's interest in the scientific aspect of the Pacific area.

The War Department's interest in the Pacific area may be said to stem from three essentials. First, together with the Navy, the War Department, through its civil affairs and military government activities, is the custodian of a large number of Pacific islands formerly owned or held by the Japanese. Along with this custodianship goes a considerable measure of responsibility for the health and welfare of the native populations. In accepting this responsibility, we must therefore interest ourselves in all phases of science which contribute to or detract from their general welfare.

As has been previously stated, the major facilities for travel and subsistence in these areas are at present under the control of the military and naval authorities. These facilities, in so far as the Army is concerned, are strained almost to the limit to meet our military and naval program in the face of drastic curtailment of personnel strength that is being brought about by the rapid demobilization of our military forces. Since any scientific expedition must at present look to these facilities for transportation and subsistence, we in turn must carefully scrutinize any proposed activity, to insure that we can in fact meet the commitments required from our own slender resources and that we do not encourage scientific expeditions by fair promises to believe that we are going to be able to do things for them which under the circumstances we may not be able to do.

A third interest in this area is the effect which the activities and conditions there may have on activities elsewhere. Tropical diseases of both plants and animals may be transmitted to or from these areas with world-wide repercussions. Air transportation, with its great speed-up, has tended to aggravate such possibilities. The study of oceanography and meteorology of these areas, as has been previously stated, may contribute greatly to our essential knowledge of these subjects.

War Department participation in activities in this area can be expected to resolve itself into several types. First, from our own selfish point of view, the most important is the assistance which we hope we may be able to get from this conference, which can be rendered to the Army and local commanders and administrators in their manifold problems of administering these areas under military control. It is readily recognized that special help is required in many of the problems dealing with native populations, their economy and social and physical well-being. It is hoped that we can look to this conference to provide a source for securing such specialized personnel.

The Army can be expected, within the limits of its resources, which I must emphasize are not great at present, to make available facilities for transportation and subsistence in the area to accredited parties and individuals engaged in scientific work in this area. The limited extent to which this can be done makes it necessary that any group contemplating such activities first clear their proposed program with the War Department in order that the theater commander can be queried and an estimate made of just how much support can be given. This is an important reason that an endeavor should be made to consolidate efforts wherever possible, and certainly not to duplicate visits and working parties to any greater extent than is necessary at this time.

As in the past, the Army may also be expected to participate actively in specific projects, those projects which appear to be of importance to our national defense program. The representatives of the technical services will be present throughout the conference, and they are prepared to discuss those projects which are of particular interest to those technical agencies. The Medical Corps, the Army Engineers, Civil Affairs, Army Air Forces, as well as the Operations Division of the War Department General Staff, all have representatives who will be present during the conference.

Again it should be remembered that our contribution of manpower and money will have to be kept within bounds of the economies that are now facing the War Department in all of its activities.

I should like again to express the appreciation of the War Department that we have been invited to participate in this conference, and I am sure that we will benefit from the results of the meeting.

CHAIRMAN GREGORY: Colonel Otis O. Benson, Army Air Forces.

COLONEL OTIS O. BENSON (Chief, Medical Research Division, Office of the Air Surgeon, Army Air Forces): Mr. Chairman, Ladies and Gentlemen: I am first asked, Dr. Gregory, to express the sincere and very deep appreciation of the Army Air Forces for being invited to attend this session. I wish next to say that, coming at this particular part of the program, following Colonel Trichel, who represents the War Department, I shall not try to detail the interests of the Army Air Forces. It would now be redundant. Our interests overlap, of course, in many instances those of the Navy and certainly those of our colleagues in the War Department.

The Air Forces find in this conference and what it implies a real opportunity to acquire information that is extremely important to them in carrying out their mission. The Air Forces, again, do desire to take part, but I am afraid that our participation will be largely that of a supporting role since the number of personnel that remain available to us for active participation is small. We are prepared, on the question of funds, to offer some support, and are offering the limited facilities of the Air Forces in the area. It is true that we do run air lines to the respective islands in many instances, and we do have bases with some maintenance personnel. As Colonel Trichel stated, these facilities are limited.

Colonel Stone, Colonel Yates, Colonel Haskins, Lieutenant Colonel Kader, and Major Crane will attend the various divisional meetings, and they will be prepared to present in some detail the interests of the Air Forces. Many of these interests have been mentioned. The Air Forces are concerned with the problems in meteorology, tropical weather, and typhoon and hurricane forecasting, as has been brought out by Admiral Conolly and Admiral Bowen. In these fields our knowledge is limited and must be greatly extended.

Since the airplane is a medium of transmitting diseases, the question of quarantine and of air-borne disease becomes a very real "Air" problem and responsibility.

We hope that a strong central organization will be established and that the agency will be totally representative. We can offer our facilities to the central agency and not have to deal with individuals scattered over the globe. I have been asked specifically to stress this thought.

Again I wish to express the appreciation of the Army Air Forces. We believe that the conference on the Pacific Sciences will develop into an important institution and one that we are prepared and anxious to support.

CHAIRMAN GREGORY: Commander Graves, speaking for Rear Admiral Earl G. Rose.

COMMANDER G. VAN A. GRAVES (Chief, Aerology and Oceanographic Section, Office of Operations, United States Coast Guard): Mr. Chairman, Members of the National Research Council, Our Hosts, and Fellow Guests: I wish to express to the Chairman the deep regret of Admiral Rose that he could not attend this conference and to assure you that it does not exhibit any lack of interest on his part in the project.

The Coast Guard is interested in almost everything on the program. Our interest springs from the fact that we have installations throughout the area where we have to maintain groups of men. Using these installations as bases, we operate surface ships, airplanes, and electronic equipment. Our interests are, therefore, primarily in meteorology, oceanography, electronics, public health, disease, food, survival, and all practical and theoretical subjects concerned with life in these areas.

The facilities which we have to offer will include material support at certain isolated locations where the Coast Guard crew are the only United States people present, and we hope it may include air and ship transportation and communication facilities, when they do not interfere with carrying out our main responsibilities in the area.

I wish again to express our deep interest in this conference and our full cooperation, whenever possible, in assisting with future projects.

CHAIRMAN GREGORY: Representing the Department of the Interior, Mr. Eric Beecroft, Special Assistant to the Secretary.

MR. ERIC BEECROFT (Special Assistant to the Secretary of the Interior): Mr. Chairman, I should like to express the deep appreciation of the Department of the Interior to the National Academy and to the National Research Council for the privilege of assisting in the fulfillment of the objectives of the Pacific Science Conference, as they are stated in the program and as they have been outlined in the clear and practical statement of Dr. Oliver. It is gratifying to find that the proposed organization of American scientists is conceived as a means of encouraging and assisting scientific research in the Pacific area and of furthering international cooperation along these lines.

There are several agencies of the Department whose scientific activities extend to this area. Representatives of these agencies—Dr. Deason, Mr. Higgins, Mr. Ralston, Mr. Ladd, and Mr. Provinse—will attend the divisional meetings and will, I know, have more detailed information about their programs and functions. For the general information of the conference, however, I shall refer to some of the principal scientific activities of the

Department and to those activities which may be greatly benefited by the advancement of science.

Fishery and Game Resources

The Secretary of the Interior is responsible for the management of certain biological resources of the Pacific Ocean pursuant to the provisions of specific international agreements and the laws of the United States. These responsibilities, delegated to a bureau within the Department called the Fish and Wildlife Service, include the management of fishery and game resources of Alaska and the Aleutian Islands; management of the fur-seal herds of the North Pacific Ocean and the Pribilof Islands; the conduct of biological and statistical investigations of whales, and the licensing of whaling activities conducted by United States nationals. The Secretary discharges the foregoing functions through the Fish and Wildlife Service, and all of them involve continuing investigations as a basis for regulation and management.

The Fish and Wildlife Service is now undertaking a program for the investigation, rehabilitation and development of the fisheries of the Philippine Islands and adjacent areas of the Pacific Ocean in accordance with the provisions of Public Law 370, approved April 30, 1946. Legislation is under consideration by the Congress which will provide for an extensive program of oceanographic and biological investigations and experimental fishing operations in the waters of Hawaii and adjacent areas of the Pacific Ocean. This proposed legislation is favored by many interests and its early passage is expected. Through the Philippine and Hawaiian investigations, as well as through the Service's fishery investigations based in the United States, a coordinated program is being developed for the study of the fishery resources that are distributed widely throughout the Pacific. As it progresses, any cooperation that Pacific Coast states and the Territory of Hawaii wish to provide will be of great assistance.

On September 28, 1945, the President of the United States issued a proclamation entitled, "Policy of the United States with respect to Coastal Fisheries in Certain Areas of the High Seas," which asserted the propriety of the establishment of conservation zones in areas of the high seas contiguous to the coasts of the United States where substantial fishing activities have been developed or maintained. If such activities have been developed and maintained by United States nationals alone, regulation of fishing activities within any established conservation zones will be undertaken by the United States. If activities within any area have been developed and maintained jointly by nationals of the United States and of other countries, conservation zones and regulation of fishing activities therein will be undertaken by international agreements. The responsibility for recommending the establishment of fishery conservation zones and for recommending appropriate administrative and regulatory measures therein is vested jointly in the Secretary of State and the Secretary of the Interior. The implementation of the foregoing Proclamation in the Pacific, which is becoming more urgent, will necessitate continuing fishery researches designed to provide for a continuous assessment of the effect of fishing activities upon the fishery resources.

Geologic Investigations of Pacific Islands

As a result of wartime experiences, the Geological Survey, early in 1945, formulated plans for postwar geological work in the Pacific. It was a comprehensive program, but attention was directed chiefly to the Japanese-mandated islands in Micronesia. This program was discussed with responsible Engineer officers and with State Department representatives. Following a formal State Department expression of interest in the program, the Corps of Engineers expressed interest in supporting it and were authorized to do so by the War Department General Staff late in 1945. Responsibility for the program was given to the Chief Engineer, AFPAC, early in 1946. Field work was started in April on Okinawa, representing the initiation of the program.

Early in the war, the Geological Survey was requested by the Corps of Engineers to provide geologic information on strategic areas. A contractual agreement was entered into whereby funds were transferred by the Corps of Engineers to the Survey for this service. This contract is still in operation; funds provided through it are supporting the present Pacific work and it is anticipated that they will be available through the fiscal year 1947.

The program, in essence, is to make systematic geologic surveys of Pacific islands remaining under U. S. control or influence. The fundamental product will be areal geologic maps at a scale suitable to the island, generally at approximately 1 : 50,000. Purely scientific researches into paleontology, stratigraphy, petrology, and physiography will be coordinated with the areal mapping. In addition, engineering geologic interpretations will be made, providing information on water supplies, foundation conditions, construction materials, and so forth. Mineral resources will be studied and evaluated.

Many of the geologic studies to be undertaken involve regional problems, the solution of which may not be found in any one island or group of islands. For this reason, certain key islands are scheduled for early work. These are, in general, the larger islands of Micronesia with more complicated geological history.

It is intended to coordinate the geologic work with other scientific projects in the area. It is understood that oceanographic studies are contemplated by the Hydrographic Office. Such studies are essential to full appreciation of the origin, structure, and form of the islands and their foundation. Agricultural soil studies should be undertaken. These can be closely integrated with the areal mapping and with physiographic studies.

A group of Survey geologists assigned to the Natural Resources Section, Supreme Command, Allied Powers, have collected Japanese data on the mineral resources of the Japanese-mandated islands, and have assembled the Japanese geologic literature on the islands.

In April of this year, field work was started on the geologic mapping of Okinawa, with a field party of four geologists. The party chief is a Survey man; two geologists are officers detailed to the work by the Army (one is on military furlough from the Survey), and one is a discharged officer employed by the Army. It is estimated that the maps and initial reports should be completed in about 14 months. The Geological Survey, of course, will make the results of this project generally available.

Present plans, definite as to scope but tentative as to scheduling, call for starting field work in the fiscal year 1946 on various islands in Micronesia.

Mapping and preliminary reports may be completed by November, 1947. This schedule calls for a minimum of twelve geologists for the fiscal year 1948.

Detailed scheduling is not yet possible far in advance, since field work must await the completion of aerial photography for topographic mapping. The completion of the geologic map is dependent upon the completion of the topographic map by the Engineer mapping battalion.

The Military Geology Unit, of the Geological Survey, is responsible for the program. A field director of the program is soon to be sent to Tokyo, where he will operate under the authority of the Chief Engineer, AFPAC, but will be responsible to the Survey. He will be charged with supervising and coordinating the field and office work, establishing schedules, forecasting personnel needs, making personnel assignments, maintaining high standards of work, and representing the Survey with Chief Engineer, AFPAC.

The Survey is responsible for staffing the program. The personnel will be largely Survey employees, but some geologists in the Army will probably be detailed to the work, as they have been on the Okinawa project.

Three other Pacific studies, under separate Survey administration and for specific immediate purposes, are now in progress.

Two Survey geologists, at State Department request, are aiding in the rehabilitation of the Philippines and assisting in the reestablishment of the Philippine Geological Survey. No comprehensive geologic work in the Philippines is now planned.

Two Survey geologists have been detailed to the U. S. Commercial Company to make reconnaissance evaluations of the mineral resources and water resources of the Micronesian Islands. Their work is largely economic, but will provide a valuable guide in planning the work of the present broad program.

Three Survey geologists are making detailed studies of Bikini Atoll in connection with the forthcoming atomic bomb tests. Their work will result in a detailed report on the various geologic aspects of Bikini and will provide a wealth of fundamental information on Pacific coral islands.

Mineral Industry in the Pacific Islands

The production of minerals and metals from the various Japanese-controlled islands was only vaguely known to the Bureau of Mines until the war was well advanced. Phosphates and bauxite were known to have been obtained from some islands, but quantitative details were lacking. Some reports have filtered through, and doubtless many more details will soon become available. Four Bureau of Mines men are in Tokyo to assist the military government in various studies of the mineral industries of Japan; and some records of production from the islands may be unearthed.

The Geological Survey's studies of areal geology, topography and general geology are fundamental to a better understanding of the possible mineral resources.

The Bureau of Mines must study what can be done with the resources which the geologist describes. What the Japanese mineral technologists had done with the mineral resources of the islands must also be studied. What vital connection the minerals had with the economy of the Japanese empire must be assessed. It is necessary to find out the minerals and the particular deposits which are still vital to the life of a subjugated Japan. What problems in mining, milling, and extraction handicapped the Japanese, and might well be solved by American methods or research? Such studies are supplementary to those of the geologist who describes the deposits and the economist who studies the production records.

Since such studies were not needed until recently, there are no appropriations available to cover them. Minor services have been afforded, such as finding a qualified man to rehabilitate and improve phosphate production on the more important islands that formerly supplied the fertilizer industry in Japan. Such a man was found for the Army, because the problem of enabling the Japanese to feed themselves is closely connected with mineral fertilizers.

It is obvious that there are mineral productions of vital interest demanding attention at once. Others are remote and deal with valuable mineral resources yet to be discovered by intensive scientific study and for which beneficiative and extractive processes remain to be worked out. No great amount of planning need be done on these latter problems until ultimate disposal of the islands has been decided.

Bureau of Reclamation

The Bureau of Reclamation activities touch to some extent on China, Hawaii, Australia, New Zealand, and India.

The Bureau is presently aiding the Territorial Government of Hawaii in an investigation of the Waimea Plateau on the island of Hawaii to determine its feasibility for irrigation. If found feasible, the irrigation project will be constructed by the Territory.

Under a contract with the Chinese Government by which funds have been advanced to cover the cost, the Bureau of Reclamation is preparing the designs and specifications for Yangtze Gorge dam in central China. The Bureau of Reclamation is not participating in the construction or financing of this project and does not know the plans of the Chinese Government in this respect.

The Governments of the Punjab, Ceylon, and Madras, have consulted the Bureau of Reclamation on technical and administrative phases of proposed irrigation and hydroelectric projects. Technical data have been exchanged and at the present time many Indian graduate engineers are visiting Bureau projects throughout the United States.

A large amount of technical data is regularly exchanged between the Bureau of Reclamation and the governments of Australia and New Zealand. Irrigation and hydroelectric engineers from those Pacific countries are frequent visitors to the Bureau offices.

Territorial Research

The Department has another type of function for which coordinated scientific research is especially vital, namely, the administration of territories and island areas. This function is assigned to the Division of Territories and Island Possessions in the office of the Secretary. Studies are in progress in the Department looking toward civil government in the islands of the Pacific which are under United States administration, subject, of course, to any international agreements as to the status of these islands. To define standards of administration effectively and to develop programs for fulfilling these standards, a maximum of scientific collaboration will be necessary between government and public and private agencies.

In connection with so-called "colonial government" (a term which is fortunately not part of our American vocabulary of public administration), it has been customary for many to think of it in terms of a specialized career service and to think of the colonies as "dependent" peoples under the tutelage of trained administrators. However, the mere fact that people are separated from the mainland by a broad expanse of water does not unfit them for potential citizenship or for attaining self-government. We have been waking up to the fact that the so-called dependent peoples don't need as much tutelage by administrators as we had thought. They do need, and ask for, our scientists and technical services. They are very likely to think of progress toward self-government, not as something merely political, but as the acquisition of technical "know-how."

The scientist is the creator in a very large measure of self-government, even if the scientist also may be said to have the power to destroy self-government. No people can be really self-governing if they haven't their own physicians, their own pharmacists, their own public works engineers, their own agricultural technicians.

Science may also be the principal factor in creating good will for American administration. Those who have been in occupied areas know that the superiority of American rule is not self-evident to the local inhabitants. It carries conviction when it takes practical form in programs of education, public health, agriculture, and other forms of technical assistance.

This is also a vital matter for the American taxpayer. If we are to assume responsibility for overseas areas, those areas must be made productive by science.

The planning of modern overseas administration is, as far as the Government is concerned, an inter-agency task. But it could be greatly facilitated by the coordinated activities of private scientific workers. I am sure that this conference and its members will give some consideration to the formulation of a scientific program to meet the near-term welfare requirements of the island peoples. A very important step in this direction has already been taken by the Reconstruction Finance Corporation in undertaking its current economic survey, enlisting the assistance on a wide scale of the Agriculture, Interior, and other Departments and personnel from the universities. The object of that survey is "to promote the more complete and efficient utilization of the area's resources for the benefit of peoples living therein in light of their local traditions and customs."

Unfortunately for the indigenous peoples, some of their gravest problems are those arising from the intrusion of outsiders. Many Pacific islanders have had their privacy rather rudely disturbed lately, and it has occurred many times in the past. The most recent impact of cultures, added to those which preceded, must represent an exciting challenge to the anthropologist and social scientist. But here, too, there is an urgent need in the interest of good government of short-term as well as long-term projects. Otherwise, it will be necessary to resort to crude expedients while the scholars are gathering notes for three-volume works.

To deal with the critical and immediate problems, it ought to be possible to distill a vast body of useful knowledge from the combined experience of, say, the Division of Territories and Island Possessions, Military Government, War Relocation, and Indian Affairs, and adding to this the contributions of the Office of Education, the Public Health Service, and other agencies.

I conclude, Mr. Chairman, with the hope that, as a result of this conference, the essential scientific substructure can be laid for prosperous and amicable relations among all Pacific peoples and in particular for enlightened administration in the areas for which the United States is responsible.

CHAIRMAN GREGORY: The Department of Agriculture, Dr. W. V. Lambert, Assistant Research Administrator.

DR. W. V. LAMBERT (Assistant Research Administrator, Department of Agriculture): Mr. Chairman, Dr. Jewett, Members of the Conference: The Agriculture Department welcomes the opportunity of participating in this conference. Aside from some experience in Hawaii, largely through cooperation with the Hawaiian Agricultural Experiment Station, the participation of representatives from our Division of Foreign Plant Introduction in the Bureau of Plant Industry, Soils and Agricultural Engineering, and the work of our personnel in military operations in the Central Pacific islands, the Department of Agriculture has had relatively little experience in that area. However, we are very much interested in seeing that these islands are developed, not only from the standpoint of improving conditions for the inhabitants, but also from the standpoint of the welfare of the American commonwealth.

The Department of Agriculture, of course, is very much interested in the development of a coordinated research program in the Central Pacific islands. Its interests are principally in the fields of soils, crops, insects, animal husbandry, and the economics of production. I shall enumerate some of the points in which we are interested in some detail, but we have representatives at the conference who will be able to discuss these in much more detail in the separate meetings.

In soils, we would be concerned first with an experiment station in the tropics where fundamental studies could be made on tropical soils. At present, no facilities of this type are available to U. S. scientists. Secondly, we would be interested in surveys of the agricultural or potential agricultural land on these islands, and the fertility needs of the agricultural soils for crop and livestock production.

From the standpoint of crops, our interests include, first, the present materials grown on the islands, including the indigenous species and varieties grown and the potential importance of each both for the agriculture of this area and for other tropical and subtropical areas in which the United States may have an interest; second, the extent to which other tropical and subtropical plants might be grown in the islands; third, the potential value of present crops for industrial or other purposes; and fourth, the extent and nature of plant diseases and parasites on each of the islands.

In the field of entomology, we would be interested, first, in a knowledge of the insect fauna of the island, especially those of importance to man, animals, and native crops; second, in the insects which are vectors of diseases; third, in the determination of the extent to which these islands may constitute hazards for the introduction of serious plant diseases into the United States and the methods for overcoming such hazards. With the large development of air traffic the accidental bringing in of insects from some of these outside areas is becoming a problem of real concern to the continental United States. Fourth, we are interested in the effect of the extensive applications of DDT during the war upon the native fauna of the islands. We lack adequate information upon that problem.

In the field of animal husbandry, our interests would include, first, the determination of existing livestock populations, including the adaptability of the various animals raised on the islands; second, an investigation of the possibilities of improvement of livestock production by the use of better adapted breeds and perhaps by the introduction of improved species, such as Indian cattle; third, a study of existing livestock diseases and parasites on the islands.

In the economics of production, our interest would center on those islands where agricultural exports might lead to the development of the area. Our studies would include a determination of the ways and means of lowering costs of production, an investigation of potential competition from other areas, and the cost of production of local food supplies.

It is at this time difficult to make recommendations relative to the organization of an over-all program to accomplish the purposes that I have mentioned here, but there are certain major considerations which those of us who are members of this conference think are essential in such a program. I shall enumerate these.

First, any coordinated scientific program that is set up in these islands should be centered at two or three major research centers, each with complete staffs and adequate library and laboratory facilities. As an example, one of these might be located at the University of Hawaii and another in the Philippines.

Second, any experimental work to be conducted away from these central stations could probably be handled, I am speaking now of agricultural interests, in field plots, by groups going to various islands where studies were necessary, or through cooperative arrangements with local organizations.

Third, the establishment of a large number of local experiment stations would be unwise because of the difficulty likely to be encountered in obtaining adequate support for such stations. Where such units are established, we believe they should be established as integral parts of the local government, and we think, furthermore, that the scientific phases of the program should be clearly differentiated from any local services. I would want to emphasize again the point which Dr. Oliver made, that the scientific men in such a program be free to carry on their work without too much consideration to local services.

Fourth, any program should provide for continuity and be sufficiently well supported to obtain the services of first-class men.

Lastly, the control over the agricultural program should rest in the Department of Agriculture, which is now carrying on an extensive program in this country and in other parts of the world. We would wish, however, to cooperate closely with other units, because we recognize that science is interdependent and that there are many things of importance to agriculture which would be developed in the medical sciences and perhaps in oceanographic studies and in other areas of science.

The National Research Council has taken a forward step, Mr. Chairman, in calling this conference, and we wish to pledge our participation within the limits of our facilities and our authorizations to take part in such a program.

CHAIRMAN GREGORY: Representing the Department of Commerce, Rear Admiral Colbert.

REAR ADMIRAL LEO O. COLBERT (Director, Coast and Geodetic Survey, Department of Commerce): Mr. Chairman, Officers of the National Research Council and of the Academy: During the war there was developed a program on prediction of radio propagation conditions in the ionosphere, supported by field stations in the Pacific area which were maintained by Army and Navy personnel and by contract work for the Office of Scientific Research and Development. The postwar program calls for the centralization of this work under the National Bureau of Standards of the Department of Commerce, with the program planning to be handled by an interdepartmental group. It aims to develop a prediction service concerning the changing conditions in the ionosphere which will result in more effective and economic use of radio communication facilities. The Weather Bureau has made noticeable advances in the prediction of the changes of weather and climate. This progress has been made under the able leadership of Dr. Reichelderfer, who will be in attendance at this conference and who has arranged to discuss desirable research programs in the meetings of the Division of Oceanography and Meteorology.

In fulfillment of its primary function of providing accurate marine charts and precise control, the Coast and Geodetic Survey has performed research in the earth sciences and in oceanography in the Hawaiian and Philippine Islands and in the adjacent ocean areas for nearly fifty years. The Coast and Geodetic Survey is concerned with further research specifically looking toward the determination of more accurate datum planes for charting and mapping, for co-tidal maps and improved tidal predictions, of gravity determinations at sea and on the land, in geo-magnetic and seismological observations, for changes taking place in the relative elevations of land and sea, and in the precise determination of the positions of islands and ocean bottom configurations in connection with a study of earth movements.

Mr. Chairman, the Secretary of Commerce, Mr. Henry A. Wallace, has requested me to express his personal interest in the purposes of this meeting. He desires to extend the cooperation of the Department of Commerce in the furtherance of coordinated research which must ultimately serve for the benefit and wellbeing not only of those peoples who inhabit these island areas but of the countries which rim the entire Pacific Basin.

CHAIRMAN GREGORY: The Public Health Service, Dr. W. H. Wright, Scientist Director.

DR. W. H. WRIGHT (Scientist Director, Public Health Service): Mr. Chairman, Dr. Jewett, Dr. Harrison, Members of the Conference: Dr. Thomas Parran, the Surgeon General of the United States Public Health Service, has asked me to assure you of his very great interest in the proceedings of this conference and to thank you on his behalf for the kind invitation for the Service to participate here in these deliberations.

By reason of its present and future responsibilities, the Public Health Service is keenly interested in health conditions in the Pacific area. In this vast region are found most of the diseases of the temperate zone as well as many of the so-called tropical diseases. The war focused attention on these latter diseases with respect to the over-all health picture in the United States, but because of the constant alertness of the medical departments of the armed services and of the Public Health Service, exotic diseases have not become established in this country.

Colonel Trichel has already touched on the question of quarantine, as have several other representatives, and it is a question, of course, in which we are extremely interested. The potentialities of disease introduction are clearly indicated by the extensive outbreak which followed the appearance of dengue in Honolulu in 1943 and the more recent importation of smallpox into certain West Coast ports. Because of these potentialities, many of the diseases found in the Pacific area must continue to be the subject of scrutiny from the standpoint of foreign quarantine.

The matter of increased air travel has been commented on previously, and undoubtedly this increased air travel will continue to bring these diseases closer to our doors. In order that quarantine may be administered efficiently, it will be necessary to have more comprehensive information concerning the distribution, epidemiology, and etiology of diseases which may be introduced through this increased foreign travel. This applies particularly to the Pacific area.

In spite of medical advances accruing from the excellent work of the various governments responsible for administering the territories within this area, of the International Health Board of the Rockefeller Foundation, and of various mission boards, actually very little research in the fields of preventive medicine and public health has been carried on in the Central or South Pacific. The paucity of funds, the scarcity of personnel, the enormous distances involved, and the previous slowness of travel have all contributed materially to this lack of accomplishment. Within the area are many conditions of unknown etiology which will no doubt require intensive study before their nature can be elucidated.

Diseases of known etiology also present many problems for investigation. The great prevalence and high mortality rate from acute respiratory diseases, enteric diseases, and tuberculosis in certain native populations warrant additional research in these problems as well as the application of sanitation and preventive measures. As we all know, parasitic diseases are widespread and are responsible for a reduction in working capacity and for considerable morbidity.

As pointed out in the 1929 report of the League of Nations' Health Section, many of the conditions found in the Pacific area present peculiarities and complexities little understood at present. Even some of the more common diseases present bizarre patterns not encountered in these same conditions in the temperate zone.

The research interests of the Public Health Service will be presented in more detail by Assistant Surgeon General R. E. Dyer, who is Director of the National Institute of Health, and who is also representing the Service in this conference.

Our interest is not confined to diseases which may be of potential importance from the standpoint of foreign quarantine. In fact, certain other problems have engaged our attention in past years in this area. Further, it is the view of the Service that parts of this region offer unique opporunities for certain additional types of medical research, and that some phases of our present research programs could be profitably pursued in other areas in the Pacific. The almost pure ethnological groups on certain islands far removed from the influences of modern civilization can be employed to considerable advantage in certain types of experimental studies requiring rigid control of extraneous factors and freedom from outside influences. The benefits to be derived from some of these projects would accrue not only to the natives of the area, but would represent contributions to the general health program in the continental United States.

Mr. Chairman, the field for medical research in the Pacific is undoubtedly so large and the opportunity so extensive that no one group can hope to embrace its multitudinous demands. Therefore, we are very glad to cooperate in evaluating the needs and in planning suitable interlocking programs which, of course, should precede active work in this field.

CHAIRMAN GREGORY: The Smithsonian Institution, Dr. Alexander Wetmore, Secretary.

DR. ALEXANDER WETMORE (Secretary, Smithsonian Institution): Mr. Chairman, Members of the Conference: In this present year of 1946, when the Smithsonian Institution completes the first hundred years of its existence, our interest in the vast Pacific area will have covered almost that same space of time. This has been mainly, though not entirely, through the work of the National Museum and its various activities. Following the founding of the Institution in 1846, there were transferred to it collections from the U. S. Exploring Expedition of 1838 to 1842 under Wilkes, the first important scientific materials of their kind gathered by our Government in the Pacific area. The years that have intervened have shown steady additions that have been augmented especially through American activities during the war and in the period immediately preceding it.

Smithsonian studies have been mainly in the systematic field, in the collection and classification of animals and plants over the vast island area and the adjacent shores. Our attempt has been to supply as much knowledge as possible as to the species or kinds that are found, the characteristics that distinguish them, and their distribution and abundance throughout the region.

The great collections made in the Pacific area by the *Albatross* and other survey ships of what was then the U. S. Fish Commission, supplemented by specimens that have come from many other sources, have been the subject of investigation by Smithsonian and associated scientists for years, with results in the form of many detailed reports. These have included descriptions of species previously unknown to science, monographs for identification in many groups, and detailed studies of distribution and habits. The work has occupied many competent scientists in a variety of fields over long periods of time.

Until World War II much of this work was regarded as an interesting addition to human knowledge, but often without particular application. With the sending of our ships and men into the Pacific, it became important at once to know the kinds of animals that might carry or transmit human disease, as well as the plant foods of jungle and shore, so that these systematic studies assumed great and immediate value.

As part of our work in these war activities, the Smithsonian arranged a special laboratory for the study of mosquitoes, where manuals were prepared for field use dealing with the disease-bearing kinds. As Japanese-held areas were invaded by our troops, it frequently happened that mosquitoes collected by technical units reached the National Museum within a week, flown to this country for study to determine what types of malaria might be expected in new battle areas. Similar studies were made of mollusks, particularly the freshwater varieties, some of which carry peculiar diseases. There were organized in the Bureau of Medicine and Survey of the Navy survey units whose duty was the collection of rats, other mammals, and various other animals that serve to carry disease, either directly in themselves or indirectly through their parasites; through these units thousands of specimens were sent to the National Museum for identification.

In these investigations we have worked in cooperation with the Navy Department, the War Department, and the Public Health Service, as well as with private institutions and individuals. The studies are part of a continuing program and are planned for such expansion as may be necessary in cooperation with other interested agencies in the future.

Great changes have come in ecological conditions in the Pacific during the period of the war, and there will be increasing change from primitive conditions in the future. It is important now to determine the forms of animals and plants, partly for historical record, as some will be reduced greatly in abundance or even will become extinct. Further, in scientific studies in any field, whether in ecology, conservation, human health, agriculture, or commerce, where native animals and plants are concerned, it is necessary to know definitely the kinds. This taxonomic knowledge is essential to all such work, and it is in this field of systematic studies that the Smithsonian through the National Museum plans to continue in cooperation with other organizations in the Pacific area.

No one here would be inclined, I think, to argue that most of this work has been done, but that argument may come from others outside. May I say that while a few groups are fairly well known, knowledge of the great majority remains imperfect. As one example, in the group of mammals about 160 islands of the 10,000 found in the Pacific have been rather completely investigated. The rest still remain practically unknown. We look forward to cooperation with others in this program in completing these gaps in existing information.

CHAIRMAN GREGORY: You know, the team mate of the National Research Council is the Social Science Research Council. The representative of this Council is Dr. Robert B. Hall.

DR. ROBERT B. HALL (Social Science Research Council): Mr. Chairman, President Jewett, Ladies and Gentlemen: I wish first, Mr. Chairman, to relay the thanks of Dr. Donald Young and the Council for our opportunity to participate in this conference and, we hope, in the objectives as well.

The Social Science Research Council, as its name implies, is concerned with the promotion of research in the social sciences. Such concern cannot reasonably have geographic limitation. Recognizing the essential unity of all knowledge, no limitation is placed on its moral support of all fields of scholarly investigation.

The Pacific Basin, with few exceptions, has to date been neglected in terms of scientific research. This applies in a spatial sense as well as in a time sense. That has been detailed most ably by practically every speaker who has preceded me. The Pacific area also offers unique opportunities for research in the social sciences, as it apparently does also in the physical sciences, and the humanities. It follows, then, that the Social Science Research Council welcomes this conference and the research objectives for which it was organized.

The Council has long been interested in and has expended considerable effort in promoting the integration of knowledge and research. The "area" (I use that word in quotes for the moment) seems a likely vehicle for such integration, provided there is a balanced representation of the different scholarly fields. The bringing together of research workers representing all of the major scientific fields and the focusing of their attention on the problems of the Pacific Basin constitute a proper step in this direction. One may suspect, however, that the Pacific Basin is several areas rather than just one. This only means that there is more work to be done.

The focusing of serious attention to scientific research, on the one-third of the earth's surface which is the Pacific Basin, will obviously constitute a long stride toward the highly desirable and inevitable goal of total world knowledge. In many fields of the social sciences such knowledge is necessary so that we may check the universality of theories developed pretty exclusively in the North Atlantic world.

Finally, the newly acquired responsibilities and belatedly recognized interests of the United States in and across the Pacific insure continued concern on the part of the Social Science Research Council in scientific research and activity in the Pacific Basin.

Mr. Chairman, may I again assure you of the continued interest of the Social Science Research Council in this project.

CHAIRMAN GREGORY: The American Council of Learned Societies, Mr. Mortimer Graves.

MR. MORTIMER GRAVES (American Council of Learned Societies): Mr. Chairman, Members of the Conference, Ladies and Gentlemen: Both you and I labor under the disability that I came in a little late, and it may very well turn out that a few things I have to say have been said, and better said, by my predecessors. That was brought home to me as I listened to my friend Bob Hall's remarks. I promise, however, that my recapitulation, if that is what it is, will be brief.

As I study the program, it seems to me that the serious business of this conference is a concern with spectacular elements in the life of the Pacific—epidemics, earthquakes, volcanoes, monsters of the deep, and things of that sort. I take it that my presence here as the representative of the American Council of Learned Societies devoted to humanistic studies, in this group of scientists, is a tacit recognition of the fact that the coverage of this conference is incomplete, rather than an attempt to get representation of the fields of study which my Council represents in this meeting.

Probably because I am an escaped scientist or a reformed scientist, having taken my A.B. in mathematics with modest distinction at Harvard College, it is fitting that I come into this scientific gathering, rather than some of my mere humanistic colleagues.

Our conception, of course—and we would not be spending our lives in the humanities if it were not our conception—is that by far the most important phenomenon to be investigated in the Pacific area or in any other region of the earth's surface is what goes on in the minds of the inhabitants. That, of course, is particularly true when you are faced with the problem of governing the inhabitants. Most colonial bungling, I dare say, that we criticize other people for, has arisen not from malevolence but rather from lack of knowledge of, or equally ignorant lack of concern for, what goes on in the minds of the people who are governed.

It is, further, our conception that the principal channel to a knowledge of phenomena of this character is by way of a study of the languages and literatures, the philosophies and religions, and the arts and histories of the people under question; and these subjects, of course, are precisely the domain of the humanities.

It follows, as Dr. Hall has pointed out, that we can have no thoroughly complete understanding of any area unless scientific work of this character is included in the study. I should be the first to confess that the humanities have not held up their end of the study of the Pacific area. I haven't time to go into the historical reasons for that, but I think it is safe to say that nowadays even in the organized humanities themselves there is no longer the conception that all knowledge and all wisdom stem from Greece and Rome, and that it is a perfectly natural move for us nowadays to include within the humanities the study of the pertinent phenomena as they are observable among peoples outside of Western Europe.

We haven't done very much in this field yet. We should start, of course, with languages. Indeed, if we could get half a dozen native speakers of some of these languages at our Linguistic Institute at the University of Michigan this summer, we should be happy to put two or three technical linguists to work on the study of the languages.

So, you see, we have an interest, although as yet very few facilities and personnel for implementing that interest. Our job, of course, is to produce that.

Those of you who have read Raymond Fosdick's latest report as President of the Rockefeller Foundation remember that he quotes, with something approximating approval, a remark by the British philosopher, C. E. M. Joad, on his first hearing of the atomic bomb. The remark was: "Will nobody stop these damned scientists!"

We have no desire at all to stop the "damned scientists," but we do want to take the opportunity of approving this recognition of the limited coverage of this conference to say that, so far as we can, we shall participate in its ends and of urging that this recognition of limited coverage be continued; in particular, that the Conference take no action which even by implication might be considered as limiting the possibility of production of more complete and fuller study of the area. Of course, we mean particularly along our lines.

Only if we can get that kind of study can the totality of American science make a contribution to the free and peaceful world of the second half of the twentieth century, to which we are all aspiring and which I am a little afraid this bifurcation between advances in the sciences and advances in what I might call the ethical studies has already rendered a little more remote than we would like it to be.

CHAIRMAN GREGORY: The American Council on Education, Dr. A. J. Brumbaugh, its Vice President.

Dr. A. J. Brumbaugh (Vice President, American Council on Education): Mr. Chairman, Members of the Conference: The American Council on Education has had a deep interest in the question of international relations and the role of education in promoting better international understanding. In line with that interest, it has developed a variety of activities relating to various countries and nations of the world. The Council's interest in the Pacific area, like its interest in other areas of the world, is focused upon education as a medium for interpreting to pupils and students in American schools the culture of the countries in the Pacific area and the scientific knowledge which is pertinent to an understanding of those countries. It is also interested in the employment of education as a channel through which American life and American culture are presented and interpreted in the foreign countries.

The Council has made only slight excursions in line with these interests into the Pacific area. I cite three activities as illustrative of practical expressions of its interest.

The Council has a standing Committee on Asiatic Studies in American Education. This Committee has held institutes for teachers in the American school systems, out of which have come plans for special projects in Asiatic studies in the American schools. The Committee has also issued bulletins of news notes containing suggestions for the improvement of Asiatic studies in the American schools. Further, the Committee has issued three special publications: one dealing with "China's Gift to the West," another with "Chinese Writing," and another with "Chinese Shadow Plays." These are all attempts to translate into' usable form essential information relating especially to Chinese life and culture. The Committee has also cooperated with the Institute of Pacific Relations in making an analysis of the treatment of China, Japan, and Southeast Asia in the American secondary school textbooks, in United States history, world history, geography and civics, and modern problems.

A second activity of the Council pertains to the rehabilitation of schools and institutions of learning in China. In this activity the Council is serving as the representative of the Department of State for the purpose of distributing grants to certain American-sponsored schools in China, these grants to be used in the purchase of supplies and materials for rehabilitation purposes. The primary objective of the program is to encourage the improvement of American-sponsored schools so that they may adequately represent within the limits of local requirements the theory and practice of education in the United States. These schools are considered the most important means of strengthening the general program of cultural understanding between the United States and China, both by bringing together children of American parentage and those of other nationalities in the United States schools abroad and by providing an understanding and appreciation of the educational principles that underlie American education. Obviously, to carry on a project of that kind, it becomes necessary to study intensively the place of American schools in a foreign culture, their effect upon foreign culture, and the effect of the foreign culture upon those schools.

The third activity of the Council, to which I wish to refer briefly, is a survey recently completed of the public schools of Hawaii. This survey was authorized by the Hawaiian territorial legislature in 1943. The purpose of the survey was to aid the Hawaiian Government in bringing about immediate improvements in the territorial schools. The survey was made under the auspices of the Council by Dr. Edgar M. Draper, Professor of Education at the University of Washington. The recommendations contained in that survey have been transmitted to the Hawaiian legislature and, by a series of resolutions, have been endorsed by that legislature. The resolutions asked the Department of Public Instruction of Hawaii to give full consideration to the recommendations contained in the survey and to use those recommendations in formulating policies, in reorganizing the curriculum, and in the further development of the public schools of the territory.

I recognize that these activities are somewhat tangential to the major emphases of your conference here. We believe, on the other hand, that education must be the medium for transmitting to the inhabitants of all the countries an understanding of the culture of their neighbors, an understanding of the scientific knowledge which makes them interdependent and which becomes a basis for the further development of scientific research.

Mr. Chairman, in so far as education has a function of that kind in the program which you are developing here, the American Council and its related organizations, I assure you, stand ready to cooperate in every way possible.

CHAIRMAN GREGORY: The Chairman of the National Research Council found it necessary to create a special organization to plan for this conference, since there was no machinery inside the Council for this purpose. I have seen some of that machinery work, and I feel that I should congratulate Dr. Harrison on the selection of the mechanics who have worked at this for the last two months or more—Dr. Murdock, Mr. Coolidge, and Dr. Darling. Dr. Murdock has taken a leading part in putting this machine together. Will you tell us how it works?

DR. GEORGE P. MURDOCK (Yale University): Mr. Chairman, Dr. Jewett, Dr. Harrison, and Fellow Members of the Conference: On behalf of the Steering Committee, I would first like to thank the speakers this morning for their interest and cooperation. I am sure we are particularly impressed by the demonstration of the State Department's interest in the area as shown by Mr. Moffat in reporting a concrete achievement in New Caledonia. We are very favorably impressed and very happy at the generous offers of assistance and cooperation that have come from all of the speakers this morning.

I think it might be worth while, for the purposes of our future discussions, to define at least the tentative limits of what we call the Pacific area. This is the Pacific Basin, the Pacific Ocean with its islands, primarily the islands of Polynesia, Melanesia, Micronesia, and Indonesia, extending to the immediately adjacent corner of Southeast Asia. We realize that in some of the scientific disciplines problems will lead beyond the limits as thus defined further into Asia, to Australia, into such eastern islands as the Galapagos and the Aleutians; in the divisional meetings problems in which these adjoining areas have elements in common with the Pacific Basin will be appropriately dealt with.

I should also like to say that the membership of this conference has been confined to American scientists. There is only one exception, Dr. Peter H. Buck, Director of the Bishop Museum, who has been invited because of his long record of achievement in Pacific anthropology, his very great contribution, and his long residence in the United States. I should like to report to those of you who do not know it, that Dr. Buck has recently been honored by a knight commandership in the Order of St. Michael and St. George, and I am sure that all the members of the conference will join with me in congratulations to the only non-American member of our group, Sir Peter Buck.

Some of you may have been puzzled at the different classifications of members and guests. I should like to state that all members, including liaison members and special guests, are welcome at any of the divisional meetings which take place this afternoon and tomorrow morning, and should feel entirely free to participate in the discussions. However, one warning. There are nearly seventy-five liaison members, and in some of the smaller divisional rooms, such as those for meteorology and the earth sciences, there are only a limited number of extra chairs. So I hope that the liaison members will not all flock together at the same time into one of the divisional rooms, but will distribute themselves so as not to cause overcrowding.

I should report that there will be plenty of chairs for everyone interested at the two joint sessions at four-fifteen this afternoon, the joint sessions on problems of the sea and on human biology and public health.

The organization meeting tomorrow afternoon will require the presence of all members and associate members. Liaison members and special guests need not attend that meeting unless they wish to do so, in which case they will be welcomed as observers. It should be pointed out, however, that the subjects to be considered will in most instances have been rather thoroughly hashed over in the previous divisional meetings.

The agenda for Saturday morning will depend largely on the results of the Friday sessions. Liaison members serving their respective agencies in an administrative capacity are urged to attend this meeting and to contribute to the discussion of the means of implementing the recommendations of the conference.

CHAIRMAN GREGORY: The meeting now stands adjourned.

[The meeting adjourned at 12:15 p. m.]

THURSDAY AFTERNOON AND FRIDAY MORNING SESSIONS

June 6 and 7, 1946

Divisional Meetings

On the afternoon of June 6th and the morning of June 7th the Conference separated into its several divisions—Anthropological Sciences, Earth Sciences, Oceanography and Meteorology, Plant Sciences, Public Health and Medicine, and Zoological Sciences. At these divisional meetings, in addition to papers and general discussion of scientific problems, the members considered questions of organization, formulated a series of tentative recommendations for a coordinated program of scientific research in the Pacific islands under American administration, and proposed a variety of recommendations for the encouragement of scientific research and activities throughout the Pacific area.

The principal organizational recommendation was one adopted by the Division of the Earth Sciences and accepted by the Division of the Anthropological Sciences to the effect that, in the permanent organization to be adopted by the Conference, the subject of anthropogeography or human geography be transferred from the Earth Sciences division to that of the Anthropological Sciences.

In the late afternoon of June 6th two special joint sessions were held on subjects of scientific interest transcending the fields of particular divisions. One was concerned with problems of the sea, overlapping the fields of geology, oceanography, and zoology. The other dealt with problems of human biology and public health, of common interest to anthropology, medicine, and certain branches of biological science.

During the evening of June 6th and the lunch hour of June 7th, three special committees met to coordinate the recommendations from the several divisions into a form suitable for presentation at the organizational meeting on the afternoon of June 7th. One special committee worked out a specific proposal for a continuing organization of Pacific scientists. A second committee synthesized the divisional proposals for research in the islands under American administration, and a third coordinated a variety of resolutions concerned with the Pacific as a whole and with areas administered by other nations. The second and third committees worked closely together, and their recommendations were later presented together.

Just prior to the organization meeting a press conference was held, at which the Steering Committee gave information and answered relevant questions about the Conference to representatives of the press.

FRIDAY AFTERNOON SESSION

June 7, 1946

ORGANIZATION MEETING

The meeting reconvened at 2:40 p. m., Dr. Robert Cushman Murphy, American Museum of Natural History, presiding.

Dr. Knowles A. Ryerson presented the recommendations of the special committee on organization. These recommendations, incorporated hereinafter as the "Proposed Organization of the Pacific Science Survey," were moved and unanimously carried.

Captain James J. Sapero (MC), USN, member of the Division of Public Health and Medicine and of the special committee on coordinating the scientific recommendations of the several divisions, presented these recommendations to the conference. After discussion and additions they were adopted in the form incorporated hereinafter as "Specific Recommendations." At the request of the third special committee, the one concerned with coordinating recommendations with respect to the Pacific as a whole and with areas administered by other nations, Captain Sapero also presented these recommendations to the conference. After discussion and changes, these were adopted in the form incorporated hereinafter as "General Recommendations" and "Recommendations pertaining to International Cooperation."

Proposed Organization of the Pacific Science Survey

It is recommended that a permanent organization be set up as follows:

1. THAT the National Research Council establish an organization, conforming as nearly as possible to its standard committee structure, to embrace American scientists concerned with Pacific research and to be called the Pacific Science Survey or some similar name.
2. THAT these scientists be organized into the following divisions, together with such other divisions as may be found desirable in the future:
   a. Anthropological Sciences (including human geography)
   b. Earth Sciences
   c. Oceanography and Meteorology
   d. Plant Sciences
   e. Public Health and Medicine
   f. Zoological Sciences
3. THAT each division be represented by a committee to be set up within the appropriate Division of the National Research Council, such committees to be called the Pacific Committee on the Anthropological Sciences, Pacific Committee on the Earth Sciences, etc.
4. THAT the central organization of the Pacific Science Survey be called the Pacific Science Board and be composed of the chairmen of the several divisional committees, together with three members at large, selected in accordance with the general practices of the National Research Council,

and that this Board be constituted as a general committee of the National Research Council.

5. THAT the divisional committees and the Pacific Science Board replace in due course all existing Pacific science committees of the National Research Council except that concerned with Pacific Science Congresses.
6. THAT one member of the Pacific Science Board be designated as Chairman of the Board, and that the Chairman together with two other members serve as the Executive Committee of the Board.
7. THAT the central office of the Pacific Science Survey be administered by an Executive Director, on salary, who shall be, ex-officio, a member at large of the Pacific Science Board.
8. THAT the Executive Director be assisted by such paid clerical and staff assistance as is desirable in view of the funds available and that he maintain close contact with the other members of the Pacific Science Board, with the divisional committees, and with such liaison or other committees as may be established.
9. THAT the Pacific Science Survey be empowered, when funds are available, to establish, staff, and equip a forward scientific station and office in the Hawaiian Islands and such field stations in other centers in the Pacific as can be arranged in cooperation with administrative agencies of the United States or with scientific or administrative agencies of foreign governments.
10. THAT the Pacific Science Board establish and maintain liaison relationships with Goverment agencies concerned with Pacific research and with nongovernmental organizations of scientists and others who are interested in furthering scientific research in the Pacific.
11. THAT each division establish a series of panels representing the major scientific interests within the division, that the several panels include American scientists in the general field who meet the qualifications for membership and are willing to serve, and that membership in the panels be determined by the divisional committee on the basis of field research in the Pacific area or comparable work on Pacific materials.
12. THAT standing committees be set up to deal with problems common to two or more divisions (for example, agriculture and nutrition), their membership to be drawn from the appropriate panels in the several divisions concerned.

Specific Recommendations

A coordinated program of scientific research for the Pacific Islands (under American or foreign administration) has been formulated. Recommendations are as follows:

I. Division of Anthropological Sciences.

General preamble. It is recommended that this Conference, in collaboration with local inhabitants, encourage investigation of problems concerning the welfare of the peoples of the Pacific Islands.

A. *General studies* that should be stressed include:

   1. A comprehensive anthropological survey, covering each of the major divisions of the subject, priority to be given to an ethnographic study of Micronesia.

2. Human geography.
3. A survey of Micronesian linguistics and the establishment of standards of phonetic transcription to be used in the publication of textbooks in the native languages.
4. A survey of the social, economic, and political structures of the present-day cultures of Micronesia.
5. Intensive study of the effects upon Micronesian societies of non-indigenous contact, such as Spanish, German, Japanese, and American culture, including alien civil administration.
6. Survey of Micronesian nutrition, diet, dietary therapeutics, food habits, and production and preparation of food.

B. *Specific studies* that should be initiated as soon as possible include:

1. A physical anthropological survey of the Micronesians.
2. Problems arising from increase and decrease of population.
3. Child growth and development.
4. Race mixture.
5. Land utilization in Micronesia, to be studied with a view to determining those areas best suited for indigenous food crops and those best suited for commercial crops.
6. Systems of land tenure, fishing rights, and property concepts in Micronesian cultures.
7. Cultural conditioning (including the effects of the school system) of the child from infancy to maturity, to be studied in significant Pacific areas by anthropologists, psychologists, and educators.
8. Native trade, and methods of developing natural resources.

II. Division of Earth Sciences.

A. *Scope.* The Earth Sciences as herein defined include Physical Geography, Geology, and Geophysics.

B. *Regions of Interest.* It is recommended that this Conference encourage a research program in the Earth Sciences for the entire Pacific Basin, with particular emphasis on Micronesia.

C. *Recommended Investigations.*

1. *Geology.* Systematic geological surveys and aerial geological mapping of selected key islands and, later, of island groups in the Pacific as a basis for scientific researches in paleontology, stratigraphy, petrology, and physiography; terrain studies and engineering-geologic interpretations of water supplies, construction materials, foundation conditions, mineral resources, and soil types.
2. *Soil Science.* Reconnaissance soil surveys of the whole Pacific area and detailed soil surveys of regions of agricultural importance, including research through field stations and field working parties for each of the principal soil types as to:
   - a. Genetic formation in relation to environment.
   - b. Mechanical properties in relation to engineering needs.
   - c. Crop adaptability and response to irrigation and fertilization in relation to production, nutrition, conservation, flood control, and land use.

3. *Agricultural Committee.* Appointment of a Committee or Division on Agriculture under the Pacific Science Survey, to assist administrators of islands in the coordination of action programs designed (a) to increase food production and improve efficiency in growing all agricultural and forest products, whether intended as food or as industrial raw materials for local industries and for commerce, and (b) to conserve soils, waters, and forests.
4. *Gravity Investigations.* Gravity observations at several atolls and at selected points about the shores of the lands and islands of the Pacific. It is recommended that a U. S. submarine, using Vening-Meinesz pendulum apparatus, be employed for one year to make gravity observations at sea, particularly in the vicinity of the Aleutian trench and other trenches. These observations are intended to increase knowledge of geological structure of seismological conditions, and of deflections of the vertical.
5. *Precise Position Determinations.* Employment of all possible means to improve the quality of basic astronomic position determinations and extend first-order triangulation when feasible, in order to obtain better basic geographic positions for airports and for Loran and other navigational installations, and for general aerial mapping.
6. *Seismology.* Establishment and permanent maintenance of four additional seismological stations containing modern seismographs at selected points in the western Pacific, to improve the science of locating and studying Pacific area earthquakes, to increase knowledge of the geologic structure of the area, to study the relations between earthquakes and seismic sea waves, and to evaluate earthquake and seismic hazards.
7. *Microseisms.* Additional study of extra-tropical meteorological disturbances in the north Pacific and Alaska area, through extending to the Aleutian Island area the observation and study of microseisms and their relation to meteorology.
8. *Seismic Prospecting.* Promotion of seismic prospecting work about the submarine trench areas and at selected points about the shores and in the depths of the Pacific, for determination of sediment depths and of underlying rock structure.
9. *Structure of Atolls.* Investigation of the structure of typical atolls, including submerged, atoll-like structures, by seismic prospecting and core drilling, magnetometer prospecting, gravitational prospecting, and detailed bathymetric surveys of their flanks and approaches.
10. *Volcanology.* Descriptive geological and geophysical observations of various types at a number of active volcanoes, particularly any volcano showing unusual activity. Modern seismic, gravimetric, electric, and magnetometric techniques should be applied to the determination of underground structure in volcanic regions.
11. *Physics of the Ionosphere and Troposphere.* Investigation of atmospheric factors influencing the propagation of electromagnetic radiation at all frequencies, in relation to radio communication and geomagnetism and to telemetering and tracking at extreme altitudes.
12. *Geomagnetism.* Establishment and maintenance of permanent magnetic observatories in the Aleutians, in the Philippines, at Samoa, and at Christmas Island or Jarvis Island, for continuous recording of

magnetic variations; employment of two field magnetometer parties for one year to investigate magnetic conditions at islands and along the shores of the Pacific, and complete repetition of such investigation after an interval of five years.

Suitable airborne magnetic instruments should be utilized and further improved as necessary for investigations generally over the Pacific Ocean area, and two planes so equipped should be employed for one year in general magnetic work. These studies are designed to improve nautical and aeronautical charts, to investigate magnetic anomalies as related to geologic structure and volcanism and to achieve other scientific results.

13. *Hydrology.* Investigation of infiltration of rainfall, stream flow and run-off, flood hazards, and preparation of isohyetal maps; investigation of storage and diversion for irrigation and hydro-electric power development, and of ground water resources; and research in dynamics of erosion.
14. *Mineral Industries.* Initiation of prospecting operations to evaluate the importance of mineral deposits in the local economy, as the information on these deposits becomes available from geological studies.
15. *Mapping Activities.* It is recommended that hydrographic, topographic, geophysical, and submarine contour mapping be supported and correlated.
16. *Geologic Timetable.* Gradual establishment of a standard stratigraphic sequence of geologic formations in the Pacific. In order to understand the succession of geologic events in the area, a geologic timetable correlating the rock formations of the islands with those of the surrounding mainlands is essential.

III. Division of Oceanography and Meteorology

The Division recommends:

A. THAT the United States immediately initiate preparations for a comprehensive program of investigations in the marine sciences in the Pacific area and that the following topics be a part of the general program of investigation.

1. Currents.
   a. The vertical, horizontal, and seasonal distribution of tidal and nontidal currents.
2. Interrelations of sea and atmosphere.
   a. Data on waves: height, length, and period, including frequency and direction of waves of different magnitudes by months.
   b. Heat exchange with atmosphere.
   c. Water exchange with atmosphere.
3. Distribution of physical properties.
   a. Complete survey, by areas and seasons, of temperature and salinity in the ocean, the variability of these characteristics, and the factors affecting this variability.
   b. Transparency of sea water and how it is affected by seasonal variations in coastal waters.
4. Distribution of chemical properties.

5. Characteristics of sea bottom.
    a. Composition, firmness, color, and geological character of bottom sediments, in offshore areas, channels, and harbor mouths.
    b. Beaches and wave zones, including trafficability characteristics of beaches and shallow water (hardness, cohesiveness, mechanical composition, and bearing capacity).
    c. Harbor and coastal silting and erosion resulting from waves and currents.

B. THAT the cooperative tidal program now in operation by the Coast and Geodetic Survey be continued and expanded in the western Pacific until observations are obtained over a sufficient period of time for a satisfactory analysis of the Pacific tides.

C. THAT support be given to the maintenance and expansion of the network of meteorological surface and upper-air stations in the Pacific area, including weather reconnaissance squadrons and special stations set up for the purpose of observing sferics, microseisms, sea swell, and radar as these relate to weather. The program would include:

1. Study of medium and high altitude meteorology (above 5000 feet), particularly of the northern and western areas.
2. Basic theoretical work on the cause and mechanism of fog and a synoptic and geographic study of the distribution of fog in the North Pacific.
3. Study of the thermal, moisture, and wind micro-structure of the lower layer of atmosphere (less than 5000 feet).
4. Research in formation, structure, and motion of typhoons.
5. Study of meteorological conditions causing anomalous propagation of ultra-high-frequency radio and radar in the western Pacific area.

D. THAT support be given to the establishment of an office to supply information regarding locations of meteorological stations and available meteorological observations, and to furnish meteorological advice to agencies or individuals planning scientific research projects in the Pacific area.

E. THAT, if expeditions are organized in the Pacific area, provision be made for taking detailed sea-surface, meteorological, and radiation observations that are necessary to investigate the energy exchange between ocean and atmosphere and to study other problems.

F. THAT, since the already available data from the Pacific area must be thoroughly studied, analyzed, and evaluated before a comprehensive and well-integrated program in oceanography (marine sciences) can be decided upon:

1. An office be established under the National Research Council to study, analyze, and evaluate the data and make the results available to the planning group.
2. This office be adequately staffed by a head scientist and necessary clerical and technical assistants.

G. THAT, because of the different requirements in the various areas and in the several fields of science, four vessels be procured, equipped, and operated for general investigations on the high seas and that eight vessels be procured, equipped, and operated for regional investigations. One of the four large vessels, and the eight smaller vessels should be used primarily for research in the natural resources of the sea and, in addition, should be equipped to participate in general oceanographic studies conducted by means of the other three large ships.

IV. Division of Plant Sciences.

A. *Whereas* there has been a lack of correlation among the botanical endeavors of scientists of different countries, and

Whereas the most rapid progress and scientific cooperation among these countries in the study of botanical problems of the Pacific will be brought about by personal contacts,

Be it resolved THAT botanical missions be sent to Japan, China (especially Formosa), and Korea (1) to obtain specimens, photographs of type and other important specimens, publications, translations of publications, and manuscripts, (2) to ascertain the needs of Pacific and Oriental botanists for corresponding scientific materials from America, and (3) to arrange for cooperation among the scientists of the participating countries.

B. *Whereas* ethnobotanical investigations are frequently neglected by both botanists and anthropologists, and

Whereas the field of ethnobotany is one in which much useful research may be done by workers in other fields,

Be it resolved THAT the National Research Council recommend methods of securing comparable linguistic terminology on economic botany and primitive agriculture from the boundaries of India through Polynesia.

C. *Whereas* the experiment station of the South Seas Bureau of the Japanese Government at Kolonia, Ponape, has a large collection of economic plants, two large modern buildings, and many acres of tillable land, and

Whereas both wet land and well-drained land have been under active cultivation, and the area is well-suited for experiment station work,

Be it resolved THAT agricultural experimentation be continued at this station.

D. *Whereas* the food production capacity of many Pacific Islands might be increased by judicious enrichment of the flora through plant introduction, and

Whereas many other products of utility might be made available to isolated peoples,

Be it resolved THAT measures be taken to introduce widely throughout the Pacific, new, useful, disease-free plants (including forest trees), favoring those that may have two or more utilities, such as use for lumber, for food, for fiber, for tannin.

E. *Whereas* modern modes of transportation and increased contacts of the island groups of the Pacific with each other and with the continents are greatly increasing the danger of spread of plant diseases,

Be it resolved THAT, whenever possible, a survey of parasitic fungi and other disease-producing organisms be made a part of plant science projects sponsored in the Pacific area ,and

Be it further resolved THAT every precaution be observed to prevent the spread of diseases and pests (including weeds). Increased attention should be given to quarantine regulations and renewed studies should be made of the efficacy of quarantine measures.

F. *Whereas* certain problems of marine biology are of practical significance in the operation of ships,

Be it resolved THAT the following studies be undertaken:

1. Biological study of the distribution and habits of marine fouling organisms.
2. Investigation of the distribution and causes of phosphorescent waters.
3. Survey of fouling in certain areas of importance to shipping in order to determine maximum depth of significant marine growth.
4. Survey in representative areas of the main marine growth forms, their seasons of attachment and rates of growth.
5. Distribution of kelp and other large algae.

V. Division of Public Health and Medicine.

The Division recommends:

A. THAT cooperative studies be conducted by qualified workers in the field of medicine, together with workers in the allied sciences, as follows:

1. Problems of the Pacific that have been demonstrated to be of particular importance to "non-immune whites."
   a. Diseases particularly prevalent in the Pacific and of major importance: dysenteries, malaria, hepatitis, dengue complex, and tropical dermatitis; also disease of lesser but peculiar importance: scrub typhus, schistosomiasis, filariasis, and Japanese B encephalitis.
   b. Dissemination and implantation of disease, with particular reference to quarantine procedures.
   c. Possible deleterious effects of widespread use of DDT.
   d. Utilization of special opportunities that may arise in the study of respiratory diseases.
   e. Determination of factors that have led to the absence of arteriosclerosis and hypertension, which are presumed to be largely or entirely absent in certain native population groups of the Pacific.
   f. Nutritional problems that arise from residence in the tropics.
2. Problems that have been demonstrated to be of particular importance to native populations.
   a. Diseases of special importance to natives, such as tuberculosis, yaws, malaria, leprosy, and helminthiases.
   b. Medical education for native doctors and nurses of the area.
   c. Feasibility of instituting modern public health procedures in certain native groups.
   d. Native nutrition.

VI. Division of Zoological Sciences.

General preamble. It is proposed that this conference aid and stimulate a broad basic program of zoological collecting in, and a study of, the land and water areas that fall within its scope. To this end it is recommended:

1. THAT a "clearing house" be established to assemble data on unstudied scientific materials from the Pacific; that such materials and specimens

be located and listed as to scope, place, time of collection, and collector; that such information be made available to all interested scientists; that staff and funds be secured for the organization, study, and identification of existing Pacific collections and for the preparation of reports, such staff and funds to be used to strengthen the appropriate departments of existing institutions.

2. THAT special attention be given to the survey of the fish life of the Pacific, including:
   a. Preparation of a bibliography of the entire Indo-Pacific fauna.
   b. Collection of specimens in all parts of Oceania.
   c. Revisions of the fauna, group by group, at several institutions.
   d. Preparation and publication of a check-list and successive revisions.
3. THAT the governments of the Philippines, of Canada, of the United States (especially in the Territory of Hawaii and the States of Washington, Oregon, and California), and other countries concerned, be encouraged to:
   a. Undertake a thorough, closely integrated investigation of the tuna-like fishes of the tropical Pacific.
   b. Coordinate their research with the needs of the industry.
4. THAT researches be conducted on the reef and lagoon fisheries of the Micronesian Islands and that the products of these fisheries be allocated for native use.
5. THAT a vessel and crew be furnished to facilitate a survey of the fishes and mollusks of the Carolines.
6. THAT advanced studies of evolution be supported by the establishment of adequate laboratory facilities in the Hawaiian Islands, where advantage can be taken of the unique development of *Drosophila* and of other animals and plants in that area, which may yield data of utmost importance bearing on the evolution of living organisms.
7. THAT the zoological survey of the Pacific area be implemented by the provision of funds for permanent staff and visiting fellows to utilize the facilities of the biological stations proposed.
8. THAT the zoological work of shore and floating biological stations relating to the marine fauna be coordinated with biological oceanographic work undertaken as part of the total survey of the Pacific envisaged.
9. THAT investigations in animal husbandry in the Pacific region be undertaken to cover:
   a. Determination of existing livestock populations, including adaptabilities.
   b. Possible improvement of livestock production by the use of better adapted breeds and improved species, such as Indian cattle.
   c. Study of existing livestock diseases and parasites on the islands.
10. THAT early and continued attention be given to the following biological problems:
   *a. Comprehensive investigations of the zooplankton.
   *b. Determination of causes and seasonal variation of phosphorescent waters.
   *c. Analysis of the character and prevalence of background noises of

---

* These should be correlated with other researches and programs in physical oceanography and marine biology. See page 40, Division of Plant Sciences, Section F.

animal origin. This will involve studies of (1) sound production, and (2) geographical and seasonal distribution of sound-producing animals and their ecological relationships.

d. Regional studies on the biology of fouling and boring organisms.
e. Researches on the biology of reef-building corals, with particular reference to composition of populations and to growth rates in different areas.
f. Ecological studies of poisonous and otherwise dangerous animals.
g. Ecological studies of termites.
h. Survey of the populations and major breeding grounds of the larger marine birds.

General Recommendations

1. *Declassification*

THAT this Conference strongly recommend that, insofar as practicable, all Pacific Island materials and information now the property of government agencies and organizations be declassified and made available to recognized scientific organizations in accordance with recommendations from the proposed Pacific Science Survey.

2. *Conservation*

THAT throughout the Pacific area every effort be made:

a. To protect and preserve areas, objects, and living species of flora and fauna having scientific, historic, or aesthetic significance, through appropriate conservation legislation, including the establishment of national parks, nature monuments, and reserves.
b. To take necessary measures to insure the preservation of flora and fauna in their native environment.
c. To set aside certain wilderness areas that are to be maintained inviolate except for essential scientific studies.
d. To determine which species are in danger of extinction and to take special measures for their protection and preservation.
e. To avoid the deliberate introduction of exotics wherever indigenous fauna or flora will be endangered, and to keep records of the intentional and accidental introduction and spread of exotic forms of animal life.
f. To minimize accidental introductions, by more effective quarantine efforts.
g. To apply caution in the use of insecticides (such as DDT), rodenticides (such as 1080), herbicides, and other chemical controls of organisms, and to carry out thorough researches on the effects of such chemicals on all forms of life, including independent investigations before, during, and after the applications.

THAT conservation regulations and the importance of protecting vanishing species from extinction be brought to the immediate attention of the establishments of the Armed Forces to prevent indiscriminate shooting or other practices that might cause the extinction of vanishing species of flora and fauna.

3. *Fellowships*

THAT the continuing organization arrange for research fellowships at varying financial grades for competent graduate students, and for grants-in-aid to established scholars, including local inhabitants, in the several fields of science involved, as a part of the mechanics of staffing research.

THAT funds be made available to foster the interchange of information on the physiology, biochemistry, and biophysics of plants of importance in the Pacific area, to allow personal contact in this field between workers of various nationalities, and to make possible the translation and publication of research results obtained during the war in former enemy and enemy-occupied territories.

4. *The Pacific War Memorial Foundation*

THAT the Pacific Science Conference approve the concept of the Pacific Foundation: "Established as a memorial to all those who served with the Armed Forces of the United States in the Pacific area." The purpose of this Foundation is to create a living war memorial devoted to the advancement of knowledge through research and conservation.

5. *Field Stations*

THAT scientific research base stations be established in Hawaii and Guam to work in close cooperation with existing research organizations and institutions in these areas.

THAT subsidiary stations be established in the following categories:

a. Floating stations consisting of vessels equipped for specific fields of research.

b. Advance base stations for both marine and terrestrial research on various types of islands and at the extremes of environmental conditions available.

c. Liaison stations to promote, in cooperation with allied agencies, research in the following areas: the Solomon Islands, Australian and Dutch New Guinea,* French Oceania,* Indonesia, the Philippines, and the Galapagos.

THAT steps be taken toward the establishment of a base research station for various types of scientific investigation in the Galapagos Islands, making use of existing installations. This base should be of a permanent nature because of the importance of maintaining continuous oceanographic, biological, and meteorological records from this island outpost of South America. By way of specific illustrations of projects for this station, it may be pointed out that various elements of the land fauna are little known; that the extraordinary humid zone of the south face of the larger islands offers the opportunity for a unique ecological mountain transect, especially from Academy Bay or Indefatigable Island; that the more barren coasts and islands afford simplified ecological conditions, comparable to those of Arctic islands, and provide a veritable field laboratory in themselves; and that the biological interest of these islands is so great that conservation measures, under the control of such a research station, are urgently required.

6. *Science Appraisal*

THAT a survey be made of the state of our knowledge in the various fields of science in the Pacific. The appraisal would have for its main object the compilation of a guide to what has been done in these fields, including a bibliography of the basic contributions. As a result of the survey, an investigator would know where further research in any field is most needed. The publication resulting from the appraisal would be a guide for investigators and administrators. In addition, the guide would help in two specific kinds of important undertaking:

---

* See recommendations pertaining to International Cooperation, page 45, Section 6 and 7.

a. Conservation measures to be agreed upon by international action.
b. Commercial policies to be evolved in progressive steps as international agreements are made necessary by problems of the use and distribution of natural resources.

7. *Documentation Centers*

THAT documentation centers be set up at Washington and at Honolulu, some of their functions to be:

a. Distribution of bibliographies on special fields.
b. Maintenance of a clearing house on current researches and projects.
c. Publication of a list of American and foreign scientists (with addresses) who have active interest in the Pacific. This list should be cross-referenced as to:
    (1) The islands or ocean areas with which each scientist has had first-hand experience.
    (2) The specific fields in which each scientist is most qualified to furnish coordinating information.
    (3) The fields in which each scientist may have become an authority even though he may not have visited or worked in the area.
d. Establishment of an archive of publications, translations, and manuscripts dealing with Pacific researches.

8. *Internships*

THAT internships on Navy Survey vessels be provided for one or more scientists, under the supervision of an experienced scientist, to gather scientific information and collections from all areas in which these vessels may operate.

9. *Pacific Congress*

THAT the projected Pacific Science Survey encourage and assist in the organization of the Seventh Pacific Science Congress as soon as possible, in order to further coordination of research already in progress or being planned and to perfect arrangements for cooperation among countries of the Pacific Basin.

10. *Check Lists of Flora and Fuana*

THAT distribution check lists of the different animal and plant groups in Oceania be prepared and published.

11. *Descriptive Geography of Micronesia*

THAT a Descriptive Geography of Micronesia be compiled, covering land forms, floral and faunal ecology, and human geography. Wherever possible, fullest use should be made of visual presentation of data, including aerial photographs that have already been taken by Army and Navy Air Forces.

12. *Scientific Appraisal at Bikini*

THAT means be provided for continuation of the appraisal of biological consequences of the atomic bomb tests at Bikini, over a period sufficiently long to cover the repopulation of the waters and lands with plant and animal life.

13. *Specific Scientific Recommendations*

THAT every assistance be given to the implementation of the specific recommendations for scientific research formulated at the conference in the fields of the anthropological sciences, the earth sciences, oceanography and meteorology, the plant sciences, public health and medicine, and the zoological sciences.

Recommendations pertaining to International Cooperation

1. THAT the Pacific Science Conference recognize the urgency of international cooperation in scientific research and to that end recommend to the Congress of the United States that the Act of August 9, 1939, which authorizes the United States to cooperate with the American Republics in scientific undertakings of mutual interest, be amended to authorize such cooperation with all foreign countries.
2. THAT the governments of the countries of the Western Pacific be invited to consider the establishment of visitors' facilities at the principal centers where considerable research facilities for resident scientists already exist.
3. THAT a committee be appointed to investigate and recommend avenues of collaboration with the United Nations and other international organizations.
4.* THAT the Pacific Science Conference urge the establishment, in cooperation with allied agencies, of liaison stations to promote research in the following areas: New Zealand, the Solomon Islands, Australian and Dutch New Guinea, French Oceania, Indonesia, the Philippines, and the Galapagos.
5. THAT the proposed Pacific Science Survey:
    a. Collaborate with interested institutions and individuals, American and foreign, in the preparation of a series of regional floras. It is suggested that a beginning be made by drawing up plans for the publication of (1) a Flora of Micronesia and (2) a Flora of the Philippines, with a judicious amount of preliminary field work in both areas.
    b. Encourage field work looking toward publication of other regional floras in the Pacific and Oriental areas.

    THAT, to forward these objectives, requests from countries interested in securing American cooperation be welcomed in order to further the preparation of regional floras, which, in preliminary editions, may extend only to the genera.

    THAT field work be encouraged in those areas for which the data in hand are obviously inadequate, as, for example, the New Hebrides and the Solomon Islands.
6. THAT the Pacific Science Conference is highly gratified to learn of the establishment of the "Institut Francais d'Oceanie" and appreciates the opportunity afforded by the invitation of the French Government to American Scientists to make use of the Institute's facilities and to cooperate with French scientists in furthering knowledge of the Pacific area through a wide range of scientific research.
7. THAT encouragement be given (a) to the establishment by the government of the Netherlands Indies of a scientific research station at Hollandia, Dutch New Guinea, and (b) to the use of former Army installa-

---

* See General Recommendations, Field Stations, page 43, 5, c.

tions for this purpose. The location of a scientific field station at Hollandia would greatly facilitate the scientific exploration of many parts of New Guinea. It is recommended that, if established, the station be provided with a small vessel suitable for coastwise operations and, if possible, plane facilities. American scientists would welcome an invitation to utilize the facilities of such a station and to cooperate with scientists working there.

8. THAT the survey of the algae and algal resources of Philippine and Indonesian waters, begun before the war by collaboration with Philippine and Dutch scientists and institutions, be continued and be extended to cover the Pacific by drawing into collaboration all agencies and persons willing to contribute toward this end. The food and fertilizer values of algae, and also their value as raw materials in the preparation of commercial products, should be appraised.
9. THAT international correlation and standardization of nomenclature and of methods of measurement be established by international committees representing all nations working in the general Pacific area. (This relates particularly to land forms, rock and soil types, geological timetables, etc.)
10. THAT the Pacific Science Conference go on record as expressing its recognition of the urgent need for support in the rehabilitation of scientific libraries and scientific collections destroyed during the war.
11. THAT in the Philippines a scientific center supported by private funds be established as an aid to scientific work and studies. Such a center should coordinate its activities with existing government bureaus and institutions.

SATURDAY MORNING SESSION

June 8, 1946

SESSION ON IMPLEMENTATION

The meeting reconvened at 9:45 a. m., Mr. Harold J. Coolidge, Museum of Comparative Zoology, Harvard University, presiding.

CHAIRMAN COOLIDGE: I want to welcome to the conference some special guests who come here from various foundations that have shown an interest in research in the Pacific. We welcome them as observers, and if they wish to take part in any of the discussions, we would like to have them feel completely free to do so.

Last night when I was leaving Dr. Mann's zoo after the smoker, there were various members of this group wandering around. In the daytime, one can see the signs which Dr. Mann has posted which say that "Lost children will be taken to the lion house." He said that that has cut down the number of lost children considerably. So, if there are any missing members of the conference, perhaps we should look in the lion house?

The program, as you all know, has been divided into three general ways of handling the subject we have come here to talk about. On the first day in the morning, we had a demonstration of interest in Pacific research by Government bureaus, departments and agencies. In the afternoon, we had the divisional meetings, where civilian scientists had a chance to express their views on these same subjects. Sometimes, on account of limitations of time, they did not all get a chance to say in open meeting what their ideas were, but there were a great many individual conferences, and I hope that most of them had a chance to get their ideas across to others who are going to be working with them on the recommendations and resolutions of this conference.

During the second day, yesterday, we were much gratified by the results of the work session. That was a day for the crystallization of plans and proposals for future research in the Pacific area. I have almost thirty pages of resolutions here which will be put in final editorial form and will be distributed to members of the conference at appropriate places and will serve as a guide for the implementation of the results of the conference.

Today, the third day, we are doing something that is usually done sometimes days, sometimes weeks, and often months after a conference takes place and resolutions are adopted. It is perhaps too bold to call this a session on implementation, but it seemed to those organizing the conference that there would be a definite value in getting together people who attended the conference and discussing some of the points where we can immediately make some concrete progress or suggestions of facilities that can be extended to further the objectives of the conference. Therefore, we might be able to make a beginning this morning in sorting out the problems of implementing the conference.

I should like to make a brief estimate of the situation as we look back over the conference and the resolutions. In all six Divisions there seemed to be a genuine concern over the lack of trained personnel in various specialties. There is no question but that we have an enormous reservoir of potential American scientists whose training has, in many instances, unfortunately been retarded on account of their war service. I think we should, however, bear in mind that if they are to devote their lives to scientific work, something should be done to give them an assurance of definite security for the future, and this means more than just brief fellowships for field work.

There is not going to be time to discuss this subject at this meeting, but clearly there should be an enlargement of permanent staffs of scientific institutions and scientific departments of universities where these men can be employed and more centers for scientific work in various parts of this country, as well as in the overseas areas which will be discussed a little later on.

The organization needed to implement the activities of the armed services in this war has had a healthy impact on the scientists at this conference because it has brought to many here an increased appreciation of the need for and value of setting up one or more Pacific scientific intelligence centers. In such intelligence centers, the materials and publications on various subjects can be deposited. Also check-lists should be compiled, and basic information in various scientific disciplines should be supplemented and added to by field surveys. This suggestion is echoed through many parts of our resolutions. These document centers (one of which is suggested for Washington and one or more in the Pacific area) should have their material well indexed, and this index should be made available to all those who would need to work with these materials.

The plans for active field work are evident throughout the resolutions, and the facilities recommended to implement these plans include several multipurpose field stations located at scientifically strategic points and also call for vessels or floating stations capable of doing oceanographic work on a large scale.

The equipment now available to carry out the plans and resolutions of this conference is by no means adequate. Some help can be obtained in the form of surplus war equipment if the disposal laws make this equipment available, but what is very much more needed is additional money, from private as well as from governmental sources, that can be devoted to the program of implementing the resolutions of this conference.

The use of many facilities has been generously offered to the scientists who will be working in the Pacific by various Government departments and agencies at our opening meeting, and I am sure that the scientific institutions that are already working on Pacific problems will be only too glad to throw open their doors and cooperate with any Government scientists and others who also could make use of their facilities.

In the implementation plans for the permanent organization which was approved yesterday, the Hawaiian Islands play a definite part. In the resolutions, the Hawaiian Islands are mentioned a number of times, and I think that in an implementation session we should hear a few words from the representatives of two of the scientific institutions in the Hawaiian Islands. First I would like to call on Dr. St. John, from the University of Hawaii, to say a few words.

DR. HAROLD ST. JOHN (University of Hawaii): Mr. Coolidge, Officers and Members of the National Research Council, Members of this Meeting, and Guests: The University of Hawaii appreciates very much the privilege of being invited to take part in this conference, partly because of our deep interest in the research problems of the Pacific.

It is appropriate for me to try to tell you something of the University of Hawaii and the possible ways in which we can contribute to this great program of research. The University of Hawaii is a land-grant institution comparable to the state universities, particularly in the western states of our country. It has about 2500 students in normal times, and it has a competent staff and excellent buildings. Most of the people who have come to visit our institution have been considerably impressed with the size and the development of it as a modern learned institution.

I think I could well mention several of the departments which might serve in this cooperative endeavor.

We have a small marine biological station in Honolulu, known for the work of Dr. C. H. Edmondson, the former Director, and Dr. R. Hiatt, who is the present Director. It has been used by many visitors. We have the book, *Marine and Shore Fauna of the Hawaiian Islands*, in a second edition, by Dr. Edmondson, which is invaluable to workers on animal marine life. We have had two books upon the fishes of the Islands written by S. Tinker and E. Y. Hosaka.

The University proper has departments of anthropology, botany, zoology, entomology, geology, geography, physics (with a seismological station), and chemistry. I may have forgotten some. We have a branch of the Federal Experimental Station, the Hawaiian Agricultural Experiment Station, large and well developed, with departments of agronomy, horticulture, parasitology, etc. There are private agricultural experimental stations in Hawaii for sugar cane and pineapple.

I will not mention the Bishop Museum because I have no doubt a representative of the Museum will speak. I am on the staff of the Bishop Museum as well as on the staff of the University of Hawaii and am one of those individuals who has tried to walk a tightrope for a good many years. As far as I know, I have still maintained my balance on that tightrope, and I do work at both institutions.

In addition to the Bishop Museum, we have two private experimental stations—the Hawaiian Sugar Planters' Experiment Station and the Pineapple Research Institute—both of which are large, well-staffed, active experimental stations, and almost every scientific visitor who comes to our island finds valuable resources and stimulating scientific companionship at those stations. I have not been given the privilege of speaking for them, but they have always cooperated in the welcoming of scientists in the past, and I am sure their facilities will be available.

I think I should mention briefly the libraries in Hawaii. We have at least five scientific libraries. The University Library is a depositary of governmental publications, is quite large, and we have long been interested in biological and physical literature of the Pacific Ocean area. The facilities of that library, and I think of all the other libraries in the city, will be freely open to any scientific visitor. I might add that there is integration in the purchases made by our own and other libraries so that whenever one institution has bought an expensive or rare book, the other four institutions refrain from buying it. That cooperative scheme enables us to make our money go further, and so when we add the total resources of all the five scientific libraries, they are considerable. Those, of course, will be available.

The University has looked with considerable interest upon the proposal that fellowships or grants-in-aid be established for the assistance or training of people interested in work on the Pacific. Our University is well-fitted in many ways to receive these fellows, guide and direct their work, and give them, if not all, at least a part of their training, and I am sure I am authorized to express our welcome to any such trainees. In the Botany Department, I would be very glad to have such people.

To take that department as an example, we have facilities which are perhaps unrivaled for the training of a person going into the Pacific islands. We are American; we speak English. That is not an uncalled for remark because we are often asked, "What language do you speak in the Hawaiian Islands?" Our flora and fauna are attenuated, specialized representations of the Southeastern Asiatic flora and fauna. If you know the flora and fauna of Western America or Central America and suddenly find yourself in the Hawaiian Islands, you will not know the species, or the genera, and you will meet a great many families you never saw or perhaps heard about before. However, if you should be investigating the plants or the animals, say, of Java, you can identify the families always, frequently genera, and occasionally even the species. This is a brief demonstration of the broad relationship of Hawaiian fauna and flora to those of other Pacific areas.

For a person going to the Pacific islands to do research work, Hawaii is a favorable place for preliminary training, because there he can become familiar with the broad groups of plants and animals he will subsequently meet. He can learn something about the conditions of tropical rain forests, which we have well developed on several of our accessible islands. Our fauna and flora are sufficiently well known, and we have local experts so that the visitor can get companionship, guidance, and help, in the literature as well as in the field.

During the last four or five years, we have welcomed experts in many lines, scientists on Government expeditions, scientists in one of the armed services, biologists, and physicists. During the time between boats or planes they come to the University or to the Hawaiian Sugar Planters' Association or to the Museum and ask for publications. These people are usually unprepared. They have had little concept of the literature available, of the work that has been done on many of the island groups, although much of that work has appeared in the various publications of the Bishop Museum.

Therefore, I would stress the point that at least a brief stopover in Honolulu would be highly desirable even for experienced men going into the Pacific because we have almost always found that we know of resources that they have never heard of before.

We have specialized on the Pacific for a long time, and naturally we gladly share our facilities. We profit from the contact with visiting experts, and we appreciate the prominence that has been given to Honolulu and its institutions in the plan laid down by this conference. We shall be glad to be recognized as one of the depositaries of the compilations, the publication, the check-lists, and so on, for our own benefit and for the benefit of future travelers.

The University has taken an active interest in the problem of research in the Pacific. In 1945, the University appointed a committee to supervise Pacific islands research and planned to start in Micronesia. That committee approached Admiral Nimitz, who was then in command at Pearl Harbor, and requested permission to do work in the American-occupied islands of Micronesia, formerly a Japanese mandate. That request was granted quickly, and almost before we were ready to go, we were given the opportunity to send a four-man expedition through Micronesia for as long as we wished.

We spent three weeks going through the Marshalls, the Marianas, and down as far as Palau, in the Carolines. We stopped on sixteen islands. We were given every type of transport available that we asked for, even special airplanes and boats. Every means of transportation, lodging, and subsistence was made available to us in a very generous way, and I can only say that if the armed forces cooperate with this larger organization as hospitably as they did with us at Christmas time, 1945, I am sure you could ask for no more. We were overwhelmed with the hospitality and the cooperation that we received.

Our University has continued with the program and in March we presented a program for further research to the Navy. It was acknowledged, but there has been no action on it. The Navy referred it to the National Research Council for recommendations. I take this opportunity to present that proposal for research now, because it seems to be the only time that it can be included on this program. I now would like to ask for action on it, because the University wants to commence work this summer. We have our party organized.

We are requesting no financial support; we are asking solely for the approval and recommendation of the work by this Council. I have handed in the full program, and will not read it, but will briefly summarize what we want to do.

The two anthropologists, Dr. John Embree and an associate, wish to work on Ponape and the Marshalls this summer. Our botanical group of three, led by myself, wishes to work in the Marshalls, on Kusaie and on Truk. Our geographical group, led by Dr. R. E. Murphy, wishes to work on Kusaie and the Marshalls. Dr. Joseph Alicata and his co-worker wish to make a parasitological survey of the island of Ponape. Three geologists, led by Dr. H. Fisher, wish to work on Yap.

Our parties are organized; they are financed. We ask the approval of this body.

Chairman Coolidge: Thank you, Dr. St. John. The question of the approval of this program and the implementation of it is something that will have to be referred to the organization which we have proposed at this conference, and there would naturally be a certain amount of time needed to get this organization set up. The implementation of the urgent part of these plans will be referred to the Continuation Committee of this conference and they may wish to take the matter up with the authorities that are in a position to be helpful and to implement those parts of the program which might be approved.

We should like to hear next from Sir Peter Buck, the Director of the Bishop Museum in Honolulu.

Dr. Peter Buck (Bishop Museum, Honolulu, Hawaii): Mr. Chairman, Ladies, and Gentlemen: The Bishop Museum was established many years ago. I don't want to go into its history, but it was established by a man with a long view into the future. He was a businessman, and he created a fund for the establishment of a museum, not only as a memorial to his wife (who was a princess of the Hawaiian line of kings) but also to conduct research, to collect, preserve, describe, and study things belonging to the Hawaiian people and kindred races.

For a number of years, the Bishop Museum has conducted research in the Polynesian area, particularly with regard to anthropology and certain of the natural sciences, such as botany, malacology, entomology, and to a certain extent marine zoology. It has been by itself to a very large extent; it has had the field to itself. It has had assistance from outside sources. It is not a wealthy institution, but it has carried on this work over a number of years.

Our Chairman of the opening day, Dr. Gregory, was the Director of the museum that expanded the work of our Museum so as to include Polynesia. We have done a great deal of work in Polynesia, and so far as anthropology is concerned, I do not think it would pay us to send any expensive expeditions into Polynesia. No work in science is ever completed. There is always something left to do and people always want to return, but so far as organized work in anthropology is concerned, we are prepared (our interest being the Polynesians) to look along the trail down which the Polynesians traveled into the group of islands which they came ultimately to settle. Whether that pathway was through Melanesia or through Micronesia, it certainly leads toward the west. Therefore, the trustees of the Bishop Museum are now in a position to cast their eyes further to the west and assist in any possible way they can in research in the western Pacific.

The University of Hawaii and the Bishop Museum have worked together in the past and they will continue to do so. There are some things that the University can handle better than we can, and maybe there are other things we can handle better than they can. Take our collections, for instance. We have an insect collection which, combined with that of the Hawaiian Sugar Planters' Association, is probably the best Pacific collection of insects there is in the world, and we are combining the two so as to further science. There is no idea of the jealousy of an individual institution; we have in mind only what are the best methods of improving science, or rather, helping it on.

We probably have the best malacological collection of land shells, and our curator of malacology, Dr. Cooke, is one of the world's authorities on the subject. We also have a good botanical collection.

Now, what I want to say is this: The Museum is there. It is not a wealthy institution. It cannot help financially, but it can help with its collections, and, so far as anthropology is concerned, we have fairly good collections from Micronesia, from the Marshall Islands and from the Carolines. There we stop. We have a little from Guam; we have never tried to collect there. We have tried to specialize within a narrower field. The material that we have, however, was collected some years ago by missionaries who were stationed out there and probably it is a tie-up with what the culture originally produced.

There is another thing that we might help with in a scheme such as the present one. We can help in anthropology. Any anthropologist, no matter from what university on the mainland, who goes into the Pacific Ocean area is going to come into contact with a background and with conditions, so far as material culture is concerned, with which he has had little experience. There is the complex around the coconut; there is the complex around pandanus, and a number of similar things for which we at the Bishop Museum over a number of years have laid down the technological processes. To my mind, the technological processes are very important. To overlook them is like attempting to study an animal and neglecting the dissection to determine the bony framework. Technological matters are complex and involve lashings and carvings, and so forth. They may appear similar microscopically, but when the technique is studied, they are found to be produced by totally different methods. Therefore, many ideas about diffusion are rejected when a closer, more intensive scientific study of technology is made.

We would be prepared with our staff at the Museum to help any anthropologists, should they care for information regarding the simpler technical processes with regard to canoes, houses, food, and so forth.

Mr. Chairman and gentlemen, the Bishop Museum believed that this conference was so important that we sent a delegation of three to represent us. We heartily approve of the whole idea.

Mention has been made before that I, as an individual, am the only foreigner present. As a foreigner, let me say that I regard this Pacific Science Survey as one of the finest things that any country could do. You have led in many things. You have led in war; you have led in peace; you have led in mechanical things, in industrialism, and so forth. You lead in science. However, by a concerted effort by everybody, by all institutions throughout the country, we can demonstrate to the world at large that the taking over of these Pacific islands is not merely a thing that we had to do because of the war, but that we are going to take them over, administer them in the proper way, and study the scientific background as has never been done before.

I, as a member of a native race from the Pacific, probably the only one here, also view with a great deal of gratification the different attitude that is taken by governments. Governments now are looking not merely for the exploitation of the commercial prospects of countries or islands that they acquire, but they believe that they have a responsibility towards the native peoples. In all our discussions of the various things that have come up, the idea in the background has been that the welfare of the native peoples of those islands must be safeguarded or improved.

I assure this conference, then, that the Museum will give the most assistance it possibly can in helping, advising, assisting, and taking part later on in expeditions. We will be glad to welcome the members who come through Honolulu on the way to the particular islands where they are going to carry out their projects. Hawaii is the gateway not to the dawn but to the sunset, and you have to pass through there. We hope that each one of you will come and call on us at the Bishop Museum.

I am so pleased, from a native point of view, that I am going to chant for you a chant, one that comes from one of the native races of the Pacific. It is a chant that was composed by the Maori people, who were living in a state of darkness which we may compare to the state of ignorance of the United States with regard to the Pacific before this war took place. There is that period of darkness in which the people are troubled. Then they see prospects, the light dawns, and knowledge comes in like the sun to spread light.

(Dr. Buck chanted the chant and then gave the English translation, as follows):

Come hither, draw nigh,
Bring unto me the living waters of life:
Ah, troubled has been the rest of the people at night,
But now it is dawn, it is dawn, it is light.

CHAIRMAN COOLIDGE: Thank you, Dr. Buck, and congratulations on having broken the stenotype machine.

I can speak at first hand about the hospitality of the islands and island people, and I know that everyone here wishes that he could accept that generous invitation that you extended. I also know that it is very gratifying to all of us who are thinking in terms of implementation of our program this morning to have these messages from the Bishop Museum and from the University. I am sure that I speak for all in assuring their representatives of our appreciation and I hope that their facilities will not only be taxed to the limit but expanded to meet the growing needs of the program which was adopted at these meetings yesterday.

We have only a limited time this morning. We have a half dozen subjects of implementation which we would like to cover, and so I shall take up next the topic of land field stations. There are many resolutions calling for the establishment of field stations as multipurpose bases for research in the Pacific.

Before setting up a new field station, one wants to know whether there are not already in existence facilities which could be adapted to the uses of visiting scientists. One of the places that was mentioned after we leave Honolulu and work out in the direction of the Philippines was the island of Guam, and I would like to know whether Commodore Rivers would be good enough to tell us whether there are any Navy facilities that he thinks would be useful as the base for a possible field station in Guam.

COMMODORE T. M. RIVERS (Rockefeller Institute for Medical Research): United States Naval Medical Research Unit No. 2, which was established on Guam, is an infant compared to the University of Hawaii and the Bishop Museum. We landed on Guam on January 12, 1945. I should like to thank the people of the University and the Bishop Museum for the help that they gave. A number of my men had the privilege of going to these institutions and having correspondence with them and obtaining a great deal of help while we were in the Pacific.

The Unit was established to study diseases of military importance in the Pacific. We were not limited to that, however. We were urged to make contributions, even during time of war, to fundamental science; that is, to medical and allied sciences. We were rather fortunate in being able to carry on these activities right in the midst of the fighting.

The war came to an end, and there is now a nice group of laboratories and buildings on Guam. I cannot speak for the Navy, and when I get through I would like to have Dr. Sapero say a few words about what use could be made of these buildings and laboratories in the future.

The United States Naval Medical Research Unit No. 2 is located on a plot of ground twenty-five acres in size, adjoining Fleet Hospital 103 and the old Fleet Hospital 111, which has been remodeled to make a hospital for natives, a school for native practitioners, and a school for native nurses. In other words, there is a little medical center there already: a hospital for Navy personnel, a hospital for natives, a native practitioners' school, a school for native nurses, and NAMRU 2, as it is called, within walking distance. On the plot of twenty-five acres, there are sixty-two buildings. It is a self-sustaining unit. It has its own transportation, its own laundry, its own galley and messing facilities, and quarters for men and officers. There are adequate facilities for administration.

The functional part of the Unit is better than the other part, but these buildings are nothing to compare with those in Honolulu. Honolulu is a delightful place, and the buildings and houses are wonderful. Most of the buildings on Guam, including the laboratories, at present are more or less barracks built like quonset huts. You will not find marble palaces and beautiful homes on Guam as you do in Honolulu. However, the laboratories themselves, I think, are as good as any laboratories you will find in the world, certainly better than the ones I have worked in. The Navy is extremely generous; it wanted to have the best laboratories possible out there, and it went out of its way to provide them.

There are a large number of laboratories. Twelve to fourteen buildings are given over to laboratories, and some have been divided in order to provide for two laboratories in one building. They are the Butler type of buildings which have been changed somewhat. They have been insulated to make them comfortable in a warm climate. A number of the laboratories are air-conditioned for certain types of work. There are instruments, such as fine balances and the current electrical equipment that is used for laboratory purposes, which will not stand up in a hot, moist climate. For instance, the Beckman apparatus will not work if you take it out of an air-conditioned building. Therefore, a number of the pieces of apparatus have to be used and kept in air-conditioned buildings.

We have two nice air-conditioned wards to take care of patients. The other day in speaking, I boasted a little about some of the facilities, but some of the boys told me afterward that I had left out a few things that I might brag about. One of them is an air-conditioned animal house. Experimental animals do not live very well in the tropics unless certain conditions are provided. We carried out a full set of experimental animals, including hamsters, cotton rats, and such things. Breeding colonies are there; at least they were when I left.

We also have a library. The Rockefeller Foundation provided the money for the library, and while I was there we were taking between forty and fifty current scientific journals, the best ones we could get, and they covered all the biological sciences. We had a fairly good field reference library. It was carefully chosen for the various disciplines.

The laboratories are on concrete decks. They have the best laboratory furniture and equipment that could be bought at the time and can accommodate many different kinds of disciplines—pathology, entomology, malacology, acarology, limnology, bacteriology, and practically all of the other sciences that have anything to do with medicine. It is silly to think that in that part of the world a physician can do the job by himself. There must be chemists, biologists, zoologists, paleontologists, and so forth, cooperating to solve the problems of medicine and human ecology.

I just wanted to give you an idea of the type of laboratories that were built on Guam and what facilities they offer to the people who wish to do scientific work in that part of the world. I would like to have Dr. Sapero speak about the disposition of these laboratories.

Captain James J. Sapero (Bureau of Medicine and Surgery, Navy Department): Mr. Chairman, I think it is unnecessary to add anything to the accurate description that Commodore Rivers has given. It is the desire of the Surgeon General that the facilities of these laboratories be turned over, as far as may be possible, to such projects in human biology and related sciences as the several divisions at this conference feel will serve a useful purpose. I think I can state very definitely for the Navy that it offers these facilities without any desire to direct scientific effort. During war time it was necessary more or less to carry on some direction of this kind; in peacetime these facilities are offered without any desire on the part of the Navy for direction. The Surgeon General would want these laboratories used for the purposes desired by the people who came there solely for those purposes and without any direction.

NAMRU No. 2 (as it was originally called) has now become a part of what is the United States Naval Medical Center of Guam, officially established by the Secretary of the Navy. The Center is composed of a Navy hospital, the Guam Memorial Hospital (which is the native hospital), and the Institute of Tropical Medicine (which was previously the Naval Medical Research Unit). There are distinct opportunities, of course, with such a center. Clinical material, in the form of the Naval personnel itself, is available should some of the problems make such necessary, and it would also be available from the native source.

The Institute is composed of a school of tropical medicine, which is essentially a school for technical work and special training in tropical problems for our own Naval personnel. Then there are the research laboratories, which are the facilities which the Navy will offer to this group to the maximum extent possible. I should say that the laboratories were built for a specific purpose, but primarily they are useful in the fields of endeavor that Commodore Rivers just mentioned to you. There are many other fields in the allied sciences, however, for which the laboratories may be used.

It is possible that the Institute of Tropical Medicine might be useful to working parties as a base from which to go out into the field and to which they could return periodically to examine their collections and prepare them for shipment or identification or further work. Therefore, it might serve not only as a home for resident scientists but also as a home base for those scientists whose work would take them out into the field.

Guam, as you know, is a communications center of the far Pacific and thus offers a unique opportunity as the far western Pacific take-off.

CHAIRMAN COOLIDGE: It is gratifying news to the conference to have the extension to this group, to the maximum extent possible, of these tangible facilities for helping to implement one important part of our program.

We have with us, as representative for Admiral Conolly, Captain Jennings, and I wonder whether he feels there are any facilities in the way of fixed installations in parts of Micronesia that might be available for a program of this group.

CAPTAIN WILLIAM S. JENNINGS (Assistant Chief of Naval Operation for Island Governments): In addition to the Institute of Tropical Medicine on Guam, the Navy is now in a position to make a concrete offer of transportation and housing facilities throughout the area. Through the medium of our outlying units, we can assist in obtaining the services of local labor and, what is more important, we can enlist the support and enthusiasm of the local native officials, without which it will be impossible to get very far in the area.

At the present time, the physical installations, except on Guam and Saipan, are in a very bad state of disrepair. On Ponape, Kusaie, Yap, and Truk, the destruction caused by our bombardments and air attacks was practically complete; very few facilities are left. However, the Japanese garrisons have now been evacuated. Our own occupational garrisons are few in number. Our military government units are located throughout the area, and we can at the present provide messing, transportation, and billeting in those places. The land is available and the local labor is available.

On Ponape, the Japs had a very fine field station which we are endeavoring to keep in *status quo*. We cannot develop it; at present we are just trying to keep it from returning to the jungle. The United States Commercial Company, working with the Navy out there, has agricultural and commercial projects throughout the area. I am sure that their facilities, along with those of the Navy, would be available as far as transportation and local contacts are concerned. In the Palaus, at Peleliu, at Yap, at Truk, and at Ponape, we have small military government garrison units to serve as focal points from which we can dispatch expeditions to the outlying atolls and islands.

As Dr. Sapero stated, so far as the Navy is cencerned, these facilities are available and there are no strings attached.

CHAIRMAN COOLIDGE: Thank you very much, Captain Jennings. That is an extremely heartening message for this implementation session.

We would like to hear now from Mr. Beecroft, the representative of the Department of the Interior, as to whether there are facilities that he feels would be helpful to our program that might be available.

MR. ERIC BEECROFT (Official Representative of the Department of the Interior): Mr. Chairman, I think it would be more appropriate if we would refer this question to the particular scientific services that are already active in the Pacific area in cooperation with the Army and the Navy. Is Dr. Deason here?

DR. HILARY J. DEASON (Fish and Wildlife Service, Department of the Interior): The Fish and Wildlife Service presently has no research stations in the South and Central Pacific Areas. If the Congress should provide the appropriation requested, the Service expects to begin, within a few months, the construction of a fishery research laboratory in the Philippine Islands in cooperation with the Philippine Government. We do not know as yet the size of that laboratory because much will depend on the amount of money appropriated and what the Filipinos are able to contribute.

In developing the program at the Philippine laboratory (which we hope will be in operation within the next year), the Fish and Wildlife Service will welcome the cooperation of any other agencies and of individual scientists who are interested in conducting research in the area. In so far as accommodations permit, the Service will be delighted to make available to collaborators and visiting scientists facilities at the new laboratory when it is completed. The foregoing represents a continuation of the policy the Fish and Wildlife Service has followed in its research laboratories in the United States of making facilities available to individual scientists. For example, the Service regularly accommodates visiting scientists at its Woods Hole (Mass.), Beaufort (N.C.), Milford (Conn.), Pensacola (Fla.), and Seattle (Wash.) laboratories.

A plan is under way, and is awaiting the passage of legislation, to establish a fishery laboratory in the Hawaiian Islands in cooperation with the Territorial Government and the University of Hawaii. The details of that project have not been completed pending passage of the proposed legislation. However, inasmuch as the Territorial Government and many institutions, organizations and individuals are interested in the project, it is possible that we will be able to undertake the construction of that laboratory within the next year or two.

We have no present plans for other permanent research stations in the Pacific. Temporary stations will be constructed or outfitted from time to time. As the research program in the Pacific develops (and we hope it will be cooperative in every sense of the word), we shall be glad to work with any other groups or individuals who may be interested.

CHAIRMAN COOLIDGE: Thank you.

MR. BEECROFT: Mr. Chairman, the other principal contribution of the Department of the Interior might be discussed briefly by Mr. Ladd, of the Geological Survey.

MR. HARRY S. LADD (U. S. Geological Survey): Mr. Chairman, the Geological Survey is already receiving cooperation from the Army and the Navy such as has been talked about this morning, and there are no strings attached to it. I made two trips to the Pacific recently, one with the Army and one with the Navy, and was given all possible consideration by the armed forces.

We have at the present time a rather large group of geologists in Tokyo. They are making an appraisal of the mineral resources of that area; also, they are attempting to bring together all of the Japanese publications, particularly on geology and mining, that have not been made available previously and many of which were published only in Japanese. We are having these translated and will certainly be glad to make these translations available to any geologists who are interested in work in the Pacific.

We also have two geologists in the Philippine Islands, and they, like the group in Tokyo, are working with the armed forces. We are hoping that we can do a great deal eventually to help the Filipino geologists. They have lost all of their libraries and most of their collections and their buildings; they have practically nothing left.

We have a geological party at present in Okinawa, and we expect to have others in Palau and in certain other islands of Micronesia this year. The Survey, however, has no idea of pre-empting the geological field in Micronesia or in other parts of the Pacific. If geologists connected with other institutions work out there, we will do all we can to cooperate with them and give what help we can.

CHAIRMAN COOLIDGE: Thank you very much. It is highly gratifying to have these messages from the Fish and Wildlife Service and the Geological Survey, which are already extremely active in the Pacific field and have such important plans for the Philippine area.

I should like now to call on a representative of the War Department, Dr. Siple, to find out whether he has any remarks he wishes to add to those that were made the other day, particularly on this subject of implementation.

DR. PAUL A. SIPLE (Research and Development Division, War Department): I am not authorized to state nor am I informed of exactly what facilities the Army could make available to scientists working under the auspices of the Pacific Science Survey. Colonel Trichel indicated with emphasis that the present Army policy does not permit the assistance of civilians in transportation, food or shelter if their occupation is other than for strictly military purposes. This policy has been necessary because of the dwindling manpower and resources of the Army overseas. This situation has arisen because of immediate circumstances and does not necessarily reflect the long-range policy. I am certain that the Army recognizes the value of the Pacific Science Survey and will cooperate as much as possible. When the plans of any scientific group have been clearly set forth and it is demonstrated that certain facilities or equipment are possessed by the Army in the vicinity where the research is to be carried on, a request through proper channels will be given consideration. It is not possible for the Army to commit itself to blanket promises at this time but it will not discourage authenticated requests for specific assistance.

CHAIRMAN COOLIDGE: Colonel Benson, have you something that you would like to say to us in connection with the Air Forces assistance in the implementation of this program as you know it now, or will that develop as time goes on?

COLONEL OTIS O. BENSON (Official Representative of the Army Air Forces): Mr. Coolidge, I think I have very little to add to what was said on the opening day except this: I will send to your board or to your central organization a list of the Air Force stations in the Pacific. We can furnish you a list of those Air Force activities that are in operation and will continue to operate. Other than that, our previous statements and commitments stand without enlargement.

CHAIRMAN COOLIDGE: We shall be pleased to have that list, and it may well be that we can work out combinations with your existing stations and plans for other stations so as to make each station as multipurpose as we can. Thank you very much.

We should like to hear now from the representative of the Department of Agriculture, Dr. Lambert, on this question of fixed stations for experimental work in the Pacific.

DR. W. V. LAMBERT (Official Representative of the Department of Agriculture): Mr. Chairman, I am afraid the Department of Agriculture is in that state of ignorance of which Sir Peter Buck spoke. Our knowledge of the Pacific is rather limited. We have done little work in the Pacific. Our major point of contact has been the Hawaiian Agricultural Experiment Station, and in any coordinated program I think probably this would continue to be our first point of contact in accordance with the policy of the Department in cooperating with these institutions in the States and territories.

We are very glad and very much gratified to see the interest in this survey that the various scientific groups are taking, because in any applied activities as they relate to agriculture in the Pacific islands, the type of information these groups accumulate would be exceedingly valuable to us. I am hoping that any organization that is set up will have central headquarters in which that type of information will be available.

As I indicated in my remarks the other morning (and I spoke only of agriculture), our thought is that we would be interested in only a few permanent experimental stations. I say that because I am thinking of the problem of getting support for such stations and maintaining such support. That is a real problem, and we speak with considerable experience because we operate many field stations in this country.

I think that some thought should be given by the survey in this coordinated program, especially as far as it relates to the governmental agencies, to making maximum use of all the experimental stations that may be established in the Pacific islands; that is, I am sure that these stations could serve practically all of the units that might want to do scientific work.

Here is another point to which we must give attention. I am sure you have considered it. I am sorry I was not able to be here yesterday. The Department of Agriculture would be very much interested in the problem of improving the status of the people in the islands and making those people self-sufficient. We do not, I am sure, want to have to support those people through subsidies or in any other manner, and I think we should give a great deal of attention to that problem. These islands should be used in a supplemental way, from the standpoint of agriculture, to grow crops that might be important to our national security and to our national welfare.

CHAIRMAN COOLIDGE: Thank you. I want to thank the Department of Agriculture for their message, and I am sure that there are many of their installations that are going to be most useful in the present and in the future and will tie in very intimately with the programs developed by the Pacific Science Survey.

I should like to call on a representative of the newly-formed Pacific Foundation, which organization was indorsed in principle—that is, the fact that a Pacific Foundation should be established—by one of the resolutions at our meeting yesterday. I know that the Pacific Foundation has thoughts and plans that might be helpful in our field station program, and I would like to ask Dr. Ripley if he would say a few words on that subject.

DR. DILLON RIPLEY (Pacific War Memorial): Mr. Chairman, I think that the primary matter of interest to the meeting at the moment, as expressed yesterday, is exactly how the proposed Pacific Foundation might eventually fit in with the Pacific Science Survey, and I would say that the question is probably open and the exact relationship is a development for the future.

The concept of the Pacific Foundation is that it should act as an operating agency in the area and gain public support for those operations through activities in connection with the development of a War Memorial. It remains to be seen, I imagine, whether the Pacific Science Survey will develop into an actual operating agency or whether it will serve as a top administrative and advisory group. If the latter should be the case, then it is the hope of the Pacific Foundation, on a lower operating level, to help as much as possible to carry out some of the programs that might be suggested. If, on the other hand, the Pacific Science Survey does become an operating agency, then the Pacific Foundation will simply be another of the operating agencies concerned with the development of research in the Pacific.

I might stress again the hope the Pacific Foundation has of developing scholarships and fellowships for research in the Pacific and stress how importantly that has been brought home to me during this meeting by the general belief that there is a great and increasing dearth of interested younger people in the problems of research of the general type that we have been discussing. I should hope that by appealing to the public of the United States to support a foundation working in the Pacific, not only would the scientific disciplines working on the Pacific be enlarged but also the interest of the public would be enlisted in this problem and their support secured.

CHAIRMAN COOLIDGE: I am sure that I speak for all of you in mentioning the fact that this plan for a Pacific Foundation has great possibilities and opens wide vistas of possible usefulness as an implementing agency on one or another level that could be helpful to the purposes of the Pacific Science Survey and could help to carry out the resolutions that were adopted yesterday.

We have had a lot of discussion of permanent fixed land field stations. Most of the Pacific, as we know, is a sea area, and there is an enormous amount of research to be done out there in oceanography and various sciences of the sea. There are plans for floating stations, for ships for oceanographic use, that come into the resolutions that were adopted by the conference yesterday. I am going to ask Dr. Sverdrup to mention the requirements that he thinks would be most urgent in connection with developing these plans, and I hope that we can have support for these requirements from those in a position to supply them.

DR. HARALD U. SVERDRUP (Director, Scripps Institution of Oceanography, California): Mr. Chairman, Ladies and Gentlemen: After the general resolution requesting a number of ships was completed yesterday, specifications as to the characteristics of these ships were also drawn up and requirements as to installations of various nature were prepared. These specific requirements have all been prepared in consultations between men interested in fisheries problems, general biology of the sea, problems in bottom sedimentation, and physical oceanography. The complete lists will be on your desk, Mr. Chairman, before this meeting closes.

We believe that the next step will be to submit the considerations of this conference to the Navy, the Army, and the U. S. Maritime Commission, in order that these agencies, as soon as possible, can be informed as to the character of ships which this conference considers would be needed for the exploration of the Pacific Ocean. It may well be stated when such requests are sent out that the United States has done less to carry out explorations of the high seas than has any nation in the northern hemisphere. That statement is somewhat too sweeping and one should not include all nations, but the lack of interest of the United States in the exploration of the oceans to date is indeed striking.

I do hope that as a result of this conference interest may be stimulated and ship facilities may be made available for our use. It is premature now to make any suggestions as to the possible operation and maintenance of ships; that matter will have to be considered at a later date.

The group in oceanography has been concerned also with another matter which we hope can be started right away. We believe that it is absolutely essential, before starting any large-scale oceanographic exploration dealing with any aspect, that the present knowledge should be surveyed; that the captured Japanese documents and all the information gathered during the war by our own forces and by our allies should be thoroughly analyzed before we attempt to outline any large-scale program.

We have suggested the establishment of an Oceanographic Office, composed of a small scientific staff with clerical and translation assistance, and with funds for travel in order that the members of that group can consult freely with experts all over the country. We are now adding the suggestion that the National Research Council approach the Office of Research and Inventions of the U. S. Navy, presenting the establishment of this office as a project for which they request the financial support of the Office of Research and Inventions. It appears that the establishment of such an office is completely within the general function of the National Research Council; furthermore, that the accumulation and analysis of all these data (many of which have immediate bearing upon such problems as were outlined by representatives of the Navy and at the opening meeting) will be an objective which the Navy will be directly interested in supporting.

I wish to state that in the establishment of this office, it is intended to avoid any duplication with existing agencies operating for similar purposes. The field of physical oceanography will be taken care of in the Hydrographic Office, but there are so many aspects of the marine sciences that a number of these have no central agency where all the information can be collected. I wish to present to you the suggestion for the establishment of such an office through the Office of Research and Inventions.

I should like to add that we have also considered the establishment of a Meteorological Office, which would serve primarily as an information center for all the different groups engaged in research which requires meteorological information. That, again, is an office which will in no way overlap the functioning of existing organizations. We have not discussed the details of how to staff an office of that sort. I know that Dr. Reichelderfer, the Chief of the United States Weather Bureau, has given the matter some thought, but I do not know whether he is prepared to make any comments at the present time. I would like to suggest, Mr. Chairman, that you ask whether he is prepared to comment.

CHAIRMAN COOLIDGE: Is Dr. Reichelderfer here?

DR. F. W. REICHELDERFER (Chief, U. S. Weather Bureau): Mr. Chairman, we have discussed what should be done in the field of meteorology, but we are not prepared to make recommendations this morning. The circumstances in meteorology are somewhat different from those in other sciences. In general, our research goes hand in hand with our daily synoptic weather analysis, and this necessitates a centralization and coordination that is not found in most other sciences. Field expeditions of a temporary nature are not so useful. It is quite possible that the existing facilities can be used without the independent action or new research organizations necessary in other fields. We are not sure of that, and we should like to consider it further and make recommendations to the Continuation Committee later on. Certainly meteorologists will welcome this research opportunity and desire to make full use of it.

While I have the floor, may I say, in connection with the remarks that have been made by other representatives of Government departments, that there undoubtedly will be Weather Bureau facilities in the Pacific of value to investigators in other fields. In general, our field buildings are small and could not offer extensive accommodations for other purposes, but in isolated places where we expect to have stations, undoubtedly the messing and billeting facilities would be a convenience to scientists who are interested in field work in those localities.

We are not sure just how extensive our stations will be. We now have before Congress estimates for stations in the Philippines. We have in process of transfer from the Army and the Navy a number of stations on islands in the Pacific which will be operated by the Weather Bureau. The number, as I say, is not known, because the military plans are not completely settled at the present time.

There are many important questions in meteorology in the Pacific that relate more or less directly to applied meteorology in the United States. Increase in our knowledge of the general circulation of the atmosphere probably would have enormous value in improving the daily weather forecasting service for all kinds of business and industrial uses in this country. Time is short and I will not amplify these brief comments now on this very important field of research and scientific development. We shall work with the Continuation Committee for the purpose of producing a program that will make the best use of the opportunity offered by the Pacific Science Conference.

CHAIRMAN COOLIDGE: Thank you.

I should like to call now on a representative of Admiral Bowen's office to find out whether he can comment on that suggestion of Dr. Sverdrup about concentrating information on oceanography and translating. Is there a representative of the Office of Research and Inventions of the Navy Department present?

LT. J. W. MOREAU (Office of Research and Inventions, Navy Department): The Navy Office of Research and Inventions will welcome any proposal which is submitted to implement the Pacific Ocean research program. The Navy will undertake fundamental research on various aspects of this program, including the translation of the Japanese documents, insomuch as the scientific investigation satisfies the Navy Department.

CHAIRMAN COOLIDGE: Is there someone here from the Navy Department who would like to say a word on the subject of the possibility of vessels being made available for research?

CAPTAIN JENNINGS: With respect to the vessels at the present time, I am quite certain, without having gone into the subject, that in order to allocate an outfit and employ a vessel for that purpose, we would probably have to have Congressional sanction. However, I am sure that the Navy will cheerfully go along with such a program and any attempt to obtain the necessary sanction and funds for carrying it out.

DR. REICHELDERFER: Mr. Chairman, on the question of vessels, I might add a point of interest. In the meteorological program, it is planned to have a number of station vessels, principally in the North Pacific, as reporting points for our daily hemisphere weather maps. Such a network was operated by the Navy during the war, and I believe that during the fiscal year 1947 it is planned to continue them west of Hawaii. They are being discontinued east of Hawaii, but the Coast Guard and the Weather Bureau are working on plans to have three vessels in that area, one in the Gulf of Alaska and two in the general region between the Hawaiian Islands and the Pacific Coast.

CHAIRMAN COOLIDGE: Are there any other representatives of Government agencies who wish to speak on this subject of facilitating the making of vessels available for this program?

DR. RICHARD H. FLEMING (Hydrographic Office, Navy Department): Mr. Coolidge, one of the resolutions which was proposed yesterday concerned the basing of scientific observers aboard survey vessels in the Pacific, and I think that I can say that the Hydrographic Office will try to make such provisions for ships that are operating in the Pacific. We will try to provide accommodations for a small group; the exact numbers I cannot specify.

It may be of interest to know that a survey vessel of the Hydrographic Office will probably be maintained in the Micronesian area for some years to come. Any observers on board will have to take potluck; they will have to go where the ship is carrying out its primary mission of surveying and take whatever facilities are available above those that are required for the operation of the survey.

The Hydrographic Office has, as Dr. Sverdrup has mentioned, a large amount of new information collected during the war and captured from the Japanese, and we will try to make that available to all scientific activities with interests in the Pacific. We hope to conduct work of our own, and contemplate oceanographic programs in the Pacific area, although there are no definite plans at the present moment. We shall offer whatever we can for cooperative undertakings, and we expect to obtain for the Hydrographic Office and for other branches of the Navy a lot of information collected by other independent activities that work in the Pacific.

The Division of Oceanography of the Hydrographic Office has been established as a central clearing house for many types of information concerning the sea, and will make the data available to the Navy and other governmental activities as well as to the public in general. We should like to emphasize the fact that we wish to receive copies of any new material from the area that may be collected.

CHAIRMAN COOLIDGE: It is very gratifying to hear that the Hydrographic Office has such an active program and that they are willing, within limitations, to share their facilities. I know that Dr. Fleming has worked very closely with Dr. Sverdrup, and I am sure that there will be the fullest cooperation in developing any of the plans of the Oceanographic Division.

We have talked about field stations; we have talked about vessels. While we are on the subject of various types of equipment, I know one question that is in many of our minds is whether it would be possibe for the surplus equipment that has been stacked up in various dumps in war areas to be made available for the use of the stations that we propose, or for assisting scientists in their activities on foreign shores or wherever they will be carrying out their missions in different parts of the Pacific. I know we would like to hear from Major Wagner, from the Office of the Foreign Liquidation Commissioner of the State Department, as to whether there are any possibilities that equipment could be made available for scientific purposes in the Pacific.

Major C. M. Wagner (Office of the Foreign Liquidation Commissioner, Department of State): I believe, from what the Navy has said in the discussion so far, that you are on the right track as far as getting your facilities is concerned. You see, the Office of the Foreign Liquidation Commissioner does not come into the picture until the Army or the Navy declares these facilities or equipment surplus to us for disposal.

You spoke primarily of the Pacific area. Our Central Field Commissioner is Mr. John K. Howard, and he is responsible for the entire Pacific area. In order to make your needs known, therefore, you should prepare a list of the items that you are interested in, and forward this list to Mr. Howard—he may have them in stock there—or you might possibly send a representative to him in Manila. We carry no inventories in the Washington office. We cannot do this because we do not have an office big enough, and, in fact, we could not keep up to date even if we did, because surplus is constantly being declared to our field commissioners and each day additional sales are being made.

I shall leave with you a list of the suboffices of the Pacific area, although, as I said before, Mr. Howard in Manila is the Central Field Commissioner, and it would be advisable to contact him directly for the items in which you are interested.

Chairman Coolidge: Scientists are always poor. Do these have to be purchased, or is there some clause which makes it possible for Mr. Howard to turn them over to projects of this nature?

Major Wagner: You are a Government agency, I take it?

Chairman Coolidge: No, this will not be a Government agency.

Major Wagner: Well, that of course throws a little different light on the situation. Equipment can be exchanged between Government agencies, but after property is declared surplus to the Office of the Foreign Liquidation Commissioner from these other agencies, the Surplus Property Act requires that it be sold. However, I believe that in a case of this kind, if it is considered a charitable or educational or other form of non-profit group, our field commissioners could possibly give you special consideration. I shall be glad to leave these addresses with you and, as I said, I think your best bet is to contact them directly. I cannot make a statement as to whether you will buy them or whether they will be donated, but I think you will have to pay for them.

Chairman Coolidge: Well, I understand that the disposal of the surplus equipment that is within the American territories, such as the Territory of Hawaii, comes under the Department of the Interior; is that right?

Major Wagner: That is right; that falls under the jurisdiction of the Department of the Interior, the same as Puerto Rico.

Chairman Coolidge: Mr. Beecroft, can you tell us whether there is any policy that would make any of that available for scientific purposes, or whether it is disposed of in the same manner as in the outer areas?

Mr. Beecroft: Mr. Chairman, the machinery in relation to Hawaii is somewhat similar to that which has been described already for the non-American areas by Major Wagner. If the Survey will deal directly in Hawaii with Colonel William Cobb, who represents the Department of the Interior there, the matter can be discussed directly in terms of the actual materials that may be declared surplus and available there.

In Washington, the head of the Surplus Property Division of the Department of the Interior is Mr. J. M. Barringer, and I think that at any time you or the representatives of the Survey would like to discuss the matter with him, he would be very glad to discuss with you the different types of materials. I should advise having lists, by way of tentative suggestions at any rate; that is, types of materials that are desirable. Also, you might ask Mr. Barringer and Colonel Cobb for lists of the types of materials that are available, so that the scientists can choose. They may think of something that those people may not think of themselves.

MAJOR WAGNER: I think what he has said covers our case.

CHAIRMAN COOLIDGE: I should like to call on Dr. Oliver, who has had considerable field experience in the Pacific, to comment on this problem.

DR. DOUGLAS OLIVER (U. S. Commercial Company): Mr. Chairman, I do not speak officially at all, but I have had recent conversations with Colonel Howard, who is the surplus property liquidator for the Pacific and China. He is also a Trustee of the New England Museum of Natural History. He is keenly interested in the Pacific Science Survey and is sitting in Manila now waiting for specific proposals to come from this survey so that he can then take them up with his principals in the State Department. He will welcome suggestions (and will push them to the extent of his authority) to turn over the surplus property facilities as they occur in the American area and throughout the rest of the Pacific. I think you will get a very warm reception from Colonel Howard.

DR. PETER BUCK: Mr. Chairman, I don't know anything about the surplus property, but it occurred to me that it will take some little time before some of these expeditions begin to work and need this equipment. Meanwhile the equipment may be disposed of. I think Honolulu, Hawaii, is a very good place, and we would be prepared to take a few microscopes and typewriters at the Bishop Museum and keep them for the expeditions. I think some scheme like that might be valuable.

CHAIRMAN COOLIDGE: I hope that the divisional chairmen will take cognizance of this fact, because then perhaps in some of these plans that we wish to implement, equipment lists can be made up early in the game, the equipment can be acquired and placed at some advance stations where it can be picked up by the field parties when they actually go into the field.

Now, is there any further comment from representatives of the State Department in connection with this matter of surplus equipment?

DR. OTTO DEGENER (New York Botanical Garden): Would not the University of Hawaii be a Government agency that might get equipment free from the Government?

MR. BEECROFT: There is already some machinery set up (the details of which I am not familiar with) to transfer surplus property to educational institutions, and I should like to suggest that even as early as Monday morning some representative of this group might approach Mr. Barringer, or his office, in the Interior Department. I should be glad to help facilitate very prompt consideration of that problem in the Department of the Interior.

CHAIRMAN COOLIDGE: One of the subjects that runs through the thread of our resolutions is the matter of fellowships, and I should like to open the meeting to any statements that anyone wishes to make with regard to the problem of fellowships and the problem of financing them. (No response.) If there is no one who wishes to speak at this time on that subject, I can only say that it is a matter of great importance to all of us that there should be additional financing to enable scientists to go into the field and carry out specific undertakings, and the people that we generally look to are the Guggenheim Foundation and other similar foundations that have fellowship programs. We hope that the representatives of those foundations may seriously consider the plans of the Pacific Science Survey at the same time that they are considering fellowship applications. We feel that if they do this, it may be possible to have the applicants for these fellowships receive the benefit of special facilities that have been talked about today, and it will be possible to accomplish a great deal more in a given length of time in Pacific research than could be accomplished under the old-fashioned pedestrian method of finding a ship and getting yourself out into the field and going through some of the trials that Dr. Oliver told us about at the opening meeting.

DR. ELMER D. MERRILL (Arnold Arboretum, Harvard University): Mr. Chairman, may I speak very briefly on this subject of fellowships, expanding the matter slightly to cover what we have been doing at the Arnold Arboretum on the basis of our own limited funds in the last decade.

I was intrigued by Sir Peter Buck's statement regarding the lack of interest in the United States with reference to the Pacific and Pacific problems, for in general, his statement was true. My personal interest in the Pacific region commenced in 1902, when I landed in Manila as government botanist, with no knowledge of the Philippine flora, little knowledge of its literature, with no library and not a botanical specimen available. I actually commenced my botanical work in Manila in a vacant building, without a chair or a table, much less a botanical book or a botanical specimen; this was starting out from scratch.

Extending explorations and working up the collections as they came in from various parts of the Philippines, it was very soon realized that we could not explain the Philippine flora without considering that of neighboring regions. Accordingly, reference collections were built up to cover the entire Indo-Malaysian, Chinese, Polynesian, and northeastern Australian regions. Gradually, on the basis of very limited funds available, our own field operations were extended southwestward into Borneo, eastward into the Mariana Islands, and northwestward into Indo-China, and southeastern China, and still later directly south into the Moluccas, because of the historical importance of the island of Amboina.

When I reported as Director of the Arnold Arboretum in 1935, I found that certain extra-budgetary funds were available. Accordingly, I utilized a considerable part of this fund to subsidize botanical field work in various parts of the Orient, and provided fellowships for graduate students who wished to matriculate at Harvard University for advanced training in botany. Some of the grants that I made were relatively small, in the $50-$200 class;

but others were rather large, amounting in some cases to $1000; and for fellowships sometimes as much as $2500. Grants were made at various times to individuals in four institutions in India, to eight institutions in China, to one or two in Japan, the Philippines, Burma, New Caledonia, Java, Singapore, and Australia. The Arnold Arboretum on its own account, previous to the war, had financed its own botanical expeditions to New Guinea, the Solomon Islands, and New Hebrides. Then a modest contribution was made to the expenses of the second and third Richard Archbold expeditions to New Guinea, just about enough to pay the salary of the botanist. As a result of this contribution the institution received the enormous botanical collections made by the Richard Archbold expeditions in various unexplored parts of New Guinea. The botanical material assembled earlier, plus that that came through the Richard Archbold expeditions, was about the only material available in the United States from the Southwestern Pacific region at the time of the outbreak of the second world war. These collections have been worked up during the war years.

I make this statement merely to show that in the field of botany there has been this long continued interest in the Orient, covering not only the Pacific Basin, but also the Philippines, the Malay Archipelago, China, Burma, Siam, French Indo-China, the Malay Peninsula, Papuasia, Fiji, Guam, northeastern Australia, and New Caledonia, on the part of one individual. This interest has been reflected in the building up of the great collections of the Bureau of Science in Manila, now unfortunately destroyed, those of the University of California, the New York Botanical Garden, and finally the Arnold Arboretum of Harvard University. Incidentally, within the last two weeks I have sent two grants, totalling $1500 to be utilized by individuals in China to finance field work, $1000 for use in Burma or Siam, and have also arranged to finance on a fellowship basis three Chinese students who are coming to Harvard for graduate work in botany. You will thus see that the botanists have not all been "asleep at the switch."

DR. PETER BUCK: Mr. Chairman, may I make a personal explanation? I made a rather sweeping statement, perhaps, as to the state of darkness of the United States concerning the Pacific before the war, but evidently it earned the commendation of all those here from the way they applauded it.

A good deal of work has been done in the Pacific area by institutions in the United States, and the Bishop Museum has been one. We have had not only ethnologists visiting practically every island group in Polynesia, but we have also had entomologists and botanists who have had expeditions all over the southern Pacific and various parts of Polynesia. We have also had expeditions into Micronesia and Fiji. We published on the archeology and culture of Guam, and we have published one volume on the insects of Guam and there is another now in press.

Therefore, I really made a mistake when I made that statement. I wish to withdraw it, sir.

DR. W. H. WRIGHT (United States Public Health Service): I don't know whether I am interposing a word here in the proper place or not, but the Public Health Service does have in operation at the present time a grants-in-aid program. This program is administered by the National Institute of Health, and it provides grants-in-aid for individuals or groups for research in medicine and in the medical sciences. It does not provide for the transfer of funds for an overall program, but it does provide for allowances for specific projects. Those projects must be approved by the National Advisory Health Council.

I am authorized by the Director of the National Institute of Health to say that the Service will look with sympathetic consideration on any applications for grants-in-aid for work in this field in the Pacific area.

DR. MERRILL: Mr. Chairman, I forgot one thing. No funds that I utilized to finance botanical work in the Orient or elsewhere, or for fellowships, came from government sources or from the foundations. Some of the money came from the general income of the Arnold Arboretum, but most of it was provided by various supporters of the institution resident in Boston, New York, Philadelphia, Chicago, and other centers, in the form of extra-budgetary funds and very largely in response to special appeals that were made from time to time. Fortunately the Arnold Arboretum does appeal to the giving public.

I cannot resist reading this little note received this morning from my secretary. I think that you will see the point. A great many of you know about the Gardner Museum in Boston, which was endowed by Mrs. Jack Gardner, who was very much of a character. My secretary writes: "A driving permit seeker just brought in such a good story that I cannot resist telling it to you. A Boston society woman approached Mrs. Jack Gardner, who, you will remember, was very severely criticized by the Boston Brahmins, and asked her for a contribution to the Charitable Eye and Ear Infirmary. 'Oh,' said Mrs. Gardner, 'I did not know that there was a charitable eye or ear in Boston.' "

Fortunately the Arnold Arboretum has not had to overcome such handicaps, and particularly in Boston appeals for support of special activities of the institution usually bring a distinctly favorable response. In the past ten years the extra-budgetary unrestricted gift-fund has received each year an average well in excess of $10,000. It was this fund that enabled the institution to do so much in the Pacific region.

CHAIRMAN COOLIDGE: We should like to have a word on matters of grants-in-aid, and if there are any foundation representatives who would like to speak on this subject, we would like to hear from them.

MR. JOHN M. RUSSELL (Markle Foundation): I am from the Markle Foundation. So many people have asked me what it is that I think I had better take a cue from Dr. St. John and explain that even though our office is on Wall Street, we are American and we do speak English. We are going through a change at the moment. Dr. Ferrell retires, and I take over on the first of July. I do not know what the future program of the Markle Foundation will be, but for a while, at least, we shall continue grants-in-aid in medical sciences.

During the war, as an emergency, we did assist in tropical medicine, and I see no reason why we would not be in a position to consider grants-in-aid for work in tropical medicine, if there is any tropical medicine left, or anything that is related thereto. I think I should point out, however, that we confine our grants-in-aid to the United States and Canada. That would merely mean that whatever funds were given would have to be given to an institution in this country, including Hawaii, or in Canada.

CHAIRMAN COOLIDGE: I am sure that could be well arranged.

Dr. Weaver, do you want to say anything about medical research in the virus field?

Dr. H. M. Weaver (National Foundation for Infantile Paralysis, Inc): There is little to add to what has already been said. I would, however, like at this time to thank the Committee on Arrangements for the opportunity to attend this conference. I am certain that the National Foundation is interested in your program and will do what it can to bring about the objectives of this conference. It is my opinion that financial support for this program might better be requested in the form of applications for specific projects rather than for the program as a whole.

Chairman Coolidge: I think that we should have a word at this time from the chairmen of the divisions who have not yet spoken this morning in case there are some resolutions that have been adopted by their divisions which they would like to mention at this implementation session.

Dr. Gregory, is there something that you would like to say?

Dr. Herbert E. Gregory (National Research Council): The Division of Earth Sciences has made what seems to me a very important decision that relates to this conference. We had to clear the slate in order to define our function. We have decided that geography as a part of geology relates to land forms and other physical features, and that geography concerned with human activities finds its appropriate place in the anthropological sciences.

The Division feels responsible for the construction of a map of the Pacific—the entire Pacific—that everybody can use. We are hoping it can be compiled from various sources and in a manner to fit into the general map of the world, on the famous one-to-a-millionth scale.

We believe that it is highly desirable to establish a geologic time scale, which we do not now have. What is the Carboniferous in the Pacific, and what does Triassic mean? Also, it is probably the job of the Division of Earth Sciences to see that the types of soil in the Pacific are determined. We feel that in stressing these activities we are providing information that all the other branches of science are desirous of having.

A good deal of what might be called "core geology" is being well studied by large groups of men, but heretofore we have paid too little attention to the periphery of geology—seismology, geophysics, and related sciences. These new subdivisions of geology seem to require field stations. We have therefore prepared a number of resolutions suggesting that facilities be made available for those groups.

Mr. Chairman, I think I might add that the Bishop Museum, which you were talking about, has had gratifying experience with grants-in-aid of research. We gave four such grants in the field of geology. Much of the modern geological work in the Pacific has been done by fellows chosen for their courage and ability.

Dr. John W. Coulter (University of Cincinnati): Mr. Chairman, I should like to say a word on behalf of that aspect of geography which was very briefly referred to in Dr. Gregory's remarks. The fact that he did not go into any more explanation was not meant to be disparaging to the field of geography which was separated. As many of you know, there has been a development in geography that is referred to as "human geography." I think it is proper that this aspect of geography be associated with the anthropological sciences, rather than the earth sciences.

I hasten to add that human geography has not at all lost its identity by being associated with the anthropological sciences. Dr. Buck whispers that it has improved its status by being associated with them. In the resolutions that were passed yesterday, as I remember it, we referred to "the anthropological sciences, including human geography," and I think that human geographers, as far as I know, would be satisfied with that kind of classification.

CHAIRMAN COOLIDGE: We should like to hear from Dr. Murdock, the Chairman of the Anthropological Division, on this point.

DR. GEORGE P. MURDOCK (Yale University): Mr. Chairman, I think the general anthropological needs have been sufficiently covered by Dr. Buck. I simply want to say one word of welcome to Dr. Coulter and his fellow human geographers in the anthropologists' lion house.

CHAIRMAN COOLIDGE: I know that we all appreciate the importance of medicine and medical research, which makes it possible for us to do other kinds of research in the Pacific, and we would like to hear from the Chairman of the Division of Public Health and Medicine, Dr. Russell.

DR. PAUL F. RUSSELL (Rockefeller Foundation): Mr. Chairman, I should like to speak first as a representative of the Rockefeller Foundation. Dr. George K. Strode, the Director of the International Health Division of that Foundation, was invited to be present but was unable to attend because it was necessary for him to attend the meeting of his Board of Scientific Directors. However, he wanted me to express his regret at not being able to be here and also his keen interest in the general purposes of this conference.

You all know the interests of the Rockefeller Foundation; it is not necessary for me to go into detail. I might point out, however, that the International Health Division of the Foundation deals through governments as a general policy, and it might be that they would look with favor on a project which involved the cooperation of some other government in the Pacific area where perhaps it might be difficult to obtain funds in other ways. For example, if the Government of Fiji or the Government of the new Philippine Republic were interested in a cooperative survey of research, it might be that the International Health Division of the Foundation would be interested in helping to support such a project. The other divisions of the Foundation, I believe, in the past have made direct grants-in-aid to worthy projects in this country, and not always through governments.

Now, Mr. Chairman, speaking as Chairman of the Division of Public Health and Medicine, I want to say that it seems to me that this implementation meeting has been very useful. For example, one of the recommendations we made in the Division of Public Health and Medicine concerned respiratory diseases. This implementation meeting has revealed methods of starting such a study project. With a grant-in-aid from the United States Public Health Service, with the splendid facilities on Guam that the Navy has offered, and with perhaps a team of young scientists keen to do this type of research, it seems to me that without very much delay we could get started.

Another interesting project which might not be subject to much delay would be to explore the very interesting fact that over a period of a year on Guam, careful post-mortem examination after every native death failed to disclose any evidence of arteriosclerosis among the natives of Guam. We do not know why, but with a grant-in-aid and with the facilities offered by the Navy, the problem might be investigated without much delay.

Mr. Chairman, I don't think I need go any farther. I simply want to reiterate that it seems to me this meeting has been very useful.

CHAIRMAN COOLIDGE: I think that it is a particular tribute to the natives of Guam that they have no hypertension, in view of the unusual strains they have been under during the war.

I know that we should like to hear from Dr. Murphy, the Chairman of the Zoological Sciences Division, if he has anything that he wishes to mention at this time.

DR. ROBERT CUSHMAN MURPHY (American Museum of Natural History): Mr. Chairman, since several institutions have been telling so modestly about their work in the Pacific, I should like to add a similarly modest word for my own institution, the American Museum of Natural History, which has undertaken and accomplished no inconsiderable research in the Pacific during many years, and not with the aid of foundations, nor with endowed funds, but rather by the same "pickpocketing" method that Dr. Merrill has found so profitable. Moreover, our institution has not lost sight of the fact that the eastern Pacific, including the coastal waters of South America, is part of the Pacific Ocean; in fact, the more that is accomplished in biological investigation, the more we find that the old division between the eastern Pacific and the so-called Indo-Pacific is breaking down.

Now, I might say that this conference has been a revelation to me of the spirit of cooperation, first in the divisional work, where we had considerable difference of opinion, and motions lost by perhaps a single vote, and later in the organization meeting yesterday, where we really accomplished a remarkable feat by ultimately carrying every motion unanimously. I think there was not a single exception.

There was a great sympathy and coordination of ideas among all members of the Zoological Division and among the divisions with which we definitely overlap, such as the Division of Oceanography and Meteorology and, I think, also the branch of anthropological science which has just been described as "human geography."

The work of the Museum in the Pacific has led to two different ends. One of them, I believe, has been a truly brilliant accomplishment in pure science through the research of such colleagues of mine as Dr. Ernst Mayr, who has attended this conference; and the other in popular education, as developed through rather extensive and elaborate exhibitions not yet completed.

Now, we have built up here a magnificent and well-coordinated program, which still needs a little further correlation and filing and smoothing. We have not concerned ourselves with the necessary corollary of really abundant funds, for which we can still only hope, but surely the spirit expressed during the whole conference represents the best hope for success, and the facilities that have been offered so freely and generously from many, many sources, governmental and private, really bode extremely well for the accomplishment of the aims that we have set.

CHAIRMAN COOLIDGE: We have not had a chance to have much discussion about various aspects of foreign cooperation in the Pacific field at this conference. There were so many things to do and there are several resolutions that bring in the other countries, but I know that it was the feeling of the conference that the next Pacific Science Congress should be held as soon as possible; I believe that will be the seventh.

Also, there is great interest on the part of the conference membership in the French Oceanic Institute, which has been established in New Caledonia and in which American scientists have been assured the use of facilities for work in those areas on a cooperative basis. We also think of our colleagues in Malaysia, New Zealand, and in Australia; we think of the Dutch and the Indonesians and all the scientists who have been in concentration camps under the Japanese, and who are now emerging with a great need for physical rehabilitation. There is the Treub Foundation laboratory and there are others in Batavia and Buitenzorg, all of which have been open in the past and will, we hope, be open in the future more and more to American scientists for research work in those areas.

An interest in future scientific cooperation has already been expressed on the part of the Siamese Government, and the French Government has expressed interest in work in Indo-China at Nhatrang. We know that the Philippines need help, and there will be plenty of chances to do important work there. Many of us think of the Raffles Museum in Singapore and are highly gratified that its collections were not destroyed during the war, and the scientists who are restaffing that Museum and the one in Kuala Lumpur are anxious to have American scientists come out and work there. The Chinese Government is also anxious that we should do cooperative work in China.

We have resolutions calling for the sending of some missions to Japan. The problem is whether permission can be received from the State Department and the Supreme Commander to send such missions to Japan. These matters will have to be worked out by the Continuation Committee.

All around the Pacific and also in some of the countries adjoining the Pacific, from South America to Canada there is interest in what we propose. The only reason that this was a closed conference is that we had to set our own house in order in the Pacific Science field. If the conference recommendations are adopted, international cooperation will play an increasing part in future developments in the Pacific.

I should like to call on the Chairman of the Steering Committee, Dr. Murdock, to make the concluding remarks.

DR. MURDOCK: Mr. Chairman, in conclusion, on behalf of the Steering Committee, I should like to thank most heartily the members for coming to this conference, so many of them from a great distance and in many cases at their own expense. Through them, I should like to thank their organizations, which, in many instances, have made it possible for them to attend. I should like particularly to thank the members who have worked on our committees and have done what seems to me a most spectacular job in bringing such order out of so wide a variety of suggestions that we could get that unanimity of action at yesterday afternoon's meeting, to which Dr. Murphy has referred. I am sure I reflect the attitude of the entire conference in extending our thanks to the representatives of the various Government departments and agencies for attending, for their very sincere interest so oftentimes expressed in our objectives, and for the many generous offers of facilities and assistance which they have made. I also feel that we owe a deep debt of gratitude to the National Research Council and to the National Academy of Sciences. In closing, I should like to propose, Mr. Chairman, the following resolution:

"RESOLVED, That the Pacific Science Conference express its deep gratitude to the National Research Council for calling and supporting the conference and to the National Academy of Sciences for providing the facilities for the meeting."

(The motion was seconded, put to a vote and unanimously carried.)

Dr. E. S. C. Handy (Bishop Museum Research Associate): It is desired to record the gratitude of the conference to the Steering Committee and particularly to Drs. Murdock, Coolidge, Gregory, and Oliver, for all that they have done to assure its success.

Chairman Coolidge: The implementation of the conference recommendations is now going to be placed in the hands of the National Research Council.

In closing this Implementation Session of the Pacific Science Conference I should like to add a final word of thanks to all of you for helping us so much this morning in really making a start towards getting concrete help and suggestions for carrying out the recommendations of the conference.

(The meeting adjourned at 12 o'clock noon.)

The following members of the conference were appointed to serve on the Continuation Committee to assist the National Research Council in the implementation of the recommendations of the Conference:

GEORGE P. MURDOCK, *Chairman*

HAROLD J. COOLIDGE, *Vice Chairman*

JOHN W. COULTER
HERBERT E. GREGORY
ELMER D. MERRILL
ROBERT CUSHMAN MURPHY
DOUGLAS L. OLIVER
PAUL F. RUSSELL
KNOWLES A. RYERSON
CAPTAIN JAMES J. SAPERO, USN
KARL P. SCHMIDT
HARALD U. SVERDRUP

Cora DuBois, alternate for George P. Murdock

Richard H. Fleming, alternate for Harald U. Sverdrup

Harry S. Ladd, alternate for Herbert E. Gregory

E. H. Walker, alternate for Elmer D. Merrill

Alexander Wetmore, alternate for Robert Cushman Murphy

CONFERENCE ATTENDANCE

NATIONAL RESEARCH COUNCIL MEMBERS

Dr. Ross G. Harrison, Chairman, National Research Council
Dr. Frank B. Jewett, President, National Academy of Sciences
Dr. George B. Darling, Executive Secretary, National Research Council
Mr. William W. Rubey, Chairman, Division of Geology and Geography
Dr. Robert F. Griggs, Chairman, Division of Biology and Agriculture
Dr. Lewis H. Weed, Chairman, Division of Medical Sciences
Dr. Walter R. Miles, Chairman, Division of Anthropology and Psychology
Dr. Glenn A. Greathouse, Director, Prevention of Deterioration Project
Dr. Herbert E. Gregory, Chairman, Committee on Pacific Investigations

MEMBERS AND ASSOCIATE MEMBERS

Division of Anthropological Sciences

Dr. George P. Murdock, Yale University, Chairman

Dr. S. D. Aberle, National Research Council
Dr. Homer G. Barnett, University of Oregon
Dr. Peter H. Buck, Director, Bishop Museum, Honolulu
Dr. Edwin G. Burrows, University of Connecticut
Dr. Cora DuBois, State Department
Dr. Fred Eggan, University of Chicago
Dr. John F. Embree, University of Hawaii
Dr. Kenneth Emory, Bishop Museum, Honolulu
Dr. Clellan S. Ford, Yale University
Dr. E. S. C. Handy, Bishop Museum Research Associate, Address, Oakton, Virginia
Dr. Felix M. Keesing, Stanford University
Dr. Raymond Kennedy, Yale University
Dr. Marshall T. Newman, Smithsonian Institution
Dr. Douglas L. Oliver, United States Commercial Company
Dr. Harry Shapiro, American Museum of Natural History
Dr. Lauriston Sharp, Department of State
Dr. Alexander Spoehr, Chicago Museum of Natural History
Dr. Laura Thompson, Department of the Interior

Division of Earth Sciences

Dr. Herbert E. Gregory, National Research Council, Chairman

Dr. Leason H. Adams, Director, Geophysical Laboratory, Carnegie Institution of Washington
Dr. John W. Coulter, University of Cincinnati
Dr. Maurice Ewing, Columbia University
Dr. John A. Fleming, Carnegie Institution of Washington
Dr. John E. Hoffmeister, University of Rochester
Dr. Harry S. Ladd, U. S. Geological Survey
Dr. W. C. Lowdermilk, Department of Agriculture
Dr. Paul H. Vestine, Carnegie Institution of Washington
Dr. H. W. Wells, Carnegie Institution of Washington

Division of Oceanography and Meteorology

Dr. Harald U. Sverdrup, Director, Scripps Institution of Oceanography, California, Chairman

Dr. Richard H. Fleming, Hydrographic Office, Navy Department
Commander G. Van A. Graves, U. S. Coast Guard
Commander C. K. Green, U. S. Coast and Geodetic Survey
Dr. Columbus O. Iselin, Woods Hole Oceanographic Institute
Dr. Robert C. Miller, Director, California Academy of Sciences
Dr. F. W. Reichelderfer, Chief, U. S. Weather Bureau

Dr. Thomas G. Thompson, Director, Oceanographic Laboratories, University of Washington
Dr. Harry Wexler, U. S. Weather Bureau

Division of Plant Sciences

Dr. Elmer D. Merrill, Director, Arnold Arboretum, Harvard University, Chairman
Dr. H. H. Bartlett, University of Michigan
Dr. Otto Degener, New York Botanical Garden
Colonel Arthur F. Fischer, former Advisor on Natural Resources to the President of the Philippines
Dr. E. P. Killip, U. S. National Museum
Dr. George F. Papenfuss, University of California
Dr. Knowles A. Ryerson, University of California, College of Agriculture
Dr. Albert C. Smith, Harvard University
Dr. Arthur R. Spillers, Department of Agriculture
Dr. Harold St. John, University of Hawaii
Dr. Walter T. Swingle, Department of Agriculture
Dr. Frans Verdoorn, Editor, Chronica Botanica
Dr. Egbert H. Walker, U. S. National Museum

Division of Public Health and Medicine

Dr. Paul F. Russell, Rockefeller Foundation, Chairman
Dr. Frederik B. Bang, Rockefeller Institute
Dr. R. E. Dyer, Director, National Institute of Health, U. S. Public Health Service
Dr. John E. Gordon, Harvard Medical School
Dr. Ira Hiscock, Yale University
Dr. Thomas M. Rivers, Rockefeller Institute for Medical Research
Captain James J. Sapero, (MC), USN, Bureau of Medicine and Surgery
Dr. Wilbur A. Sawyer, Director of Health, United Nations Relief and Rehabilitation Administration
Brigadier General James S. Simmons, USA, Chief, Preventive Medicine Service, Office of the Surgeon General
Dr. Willard H. Wright, Chief, Zoology Laboratory, U. S. Public Health Service

Division of Zoological Sciences

Dr. Robert Cushman Murphy, American Museum of Natural History, Chairman
Lieutenant R. Tucker Abbot, Museum of Comparative Zoology, Harvard University
Lieutenant Rollin H. Baker, U. S. National Museum
Dr. Martin Burkenroad, Yale University
Dr. W. M. Chapman, California Academy of Sciences
Dr. Frances Clark, California State Fisheries Laboratory
Dr. William J. Clench, Museum of Comparative Zoology, Harvard University
Mr. Harold J. Coolidge, Museum of Comparative Zoology, Harvard University
Dr. C. H. Curran, American Museum of Natural History
Dr. H. G. Deignan, U. S. National Museum
Dr. Carl L. Hubbs, Scripps Institution of Oceanography, California
Dr. Laurence Irving, Swarthmore College
Dr. David H. Johnson, U. S. National Museum
Dr. A. Remington Kellogg, U. S. National Museum
Dr. William M. Mann, Director, National Zoological Park
Dr. Ernst Mayr, American Museum of Natural History
Dr. George S. Myers, Natural History Museum, Stanford University
Dr. Dillon Ripley, Litchfield, Connecticut (Yale University)
Dr. H. Radclyffe Roberts, Academy of Natural Sciences, Philadelphia
Dr. Karl P. Schmidt, Chicago Museum of Natural History
Dr. Waldo L. Schmitt, U. S. National Museum
Mr. O. E. Sette, Fish and Wildlife Service
Dr. G. H. Tate, American Museum of Natural History
Dr. Edward H. Taylor, University of Kansas
Dr. Robert L. Usinger, University of California, College of Agriculture
Dr. Alexander Wetmore, Secretary, Smithsonian Institution
Dr. Elwood C. Zimmerman, Bishop Museum, Honolulu

LIAISON MEMBERS

Department of State

Hon. Abbot Low Moffat, Chief, Division of Southeast Asian Affairs
Mr. S. W. Boggs, Office of the Special Assistant to the Secretary
Mr. Leslie Brady, Office of International Information and Cultural Affairs
Mr. Eugene P. Chase, Division of Dependent Areas
Dr. Cora DuBois, Division of Research
Dr. William E. S. Flory, International Resources Division
Mr. Holden Furber, Division of British Commonwealth
Mr. Hillis Lory, Division of Japanese Affairs
Mr. Edward W. Mill, Division of Philippine Affairs
Mr. Emil J. Sady, Division of Dependent Areas
Dr. Lauriston Sharp, Division of Southeast Asian Affairs
Mr. George Taylor, Office of Information and Cultural Affairs
Major Carl M. Wagner, Office of the Foreign Liquidation Commissioner

War Department

Colonel G. W. Trichel, GSC, Chief, Research and Development Division, General Staff
Mr. Mark P. Connaughton, Office of Engineers
Mr. John E. Jackson, G-2, Scientific Section
Colonel F. S. Knoblauch, MC, Office of the Surgeon General
Colonel K. R. Lundeberg, MC, Office of the Surgeon General
Colonel Herbert Milwit, Corps of Engineers
Mr. G. M. Pollard, Civil Affairs
Colonel Sidman P. Poole, WDGS, Intelligence Division
Dr. Paul A. Siple, Research and Development Division
Mrs. F. H. Whedon, Meteorology

Army Air Forces

Colonel Otis O. Benson, MC, Chief, Medical Research Division, Office of the Air Surgeon
Major Ralph L. Bennett, HQ, Air Weather Service
Lieutenant Colonel Evan F. Bourne, HQ, Air Weather Service
Major R. T. Crane, Special Project
Colonel Millard C. Haskin, AC, Air Materiel Command
Mr. Woodrow C. Jacobs, Air Weather Service
Mr. R. G. Stone, Air Weather Service
Colonel William S. Stone, MC, Preventive Medicine
Colonel Laurence F. Tanberg, AC, Air Materiel Command
Lieutenant Colonel George W. Taylor, AC, Operation Analysis Section
Colonel D. N. Yates, AC, Meteorology

Navy Department

Vice Admiral Richard L. Conolly, USN, Deputy Chief of Naval Operations
Rear Admiral H. G. Bowen, Chief, Office of Research and Inventions
Captain Robert D. Conrad, USN, Office of Research and Inventions
Commander Charles J. Fish, USNR, Operational Readiness Division
Dr. Richard H. Fleming, Hydrographic Office
Captain William S. Jennings, USN, Assistant Chief of Naval Operations for Island Governments
Lieutenant Commander Kenneth L. Knight, USNR, Bureau of Medicine and Surgery
Commander R. H. Maynard, Aerology Division
Captain H. T. Orville, USN, Chief, Aerology Division
Dr. L. H. Rumbaugh, Naval Ordnance Laboratory
Captain James J. Sapero (MC), USN, Bureau of Medicine and Surgery
Dr. Kenneth V. Thimann, Operational Readiness Division

United States Coast Guard

Commander G. Van A. Graves, USCG, Chief, Aerology and Oceanographic Section, Office of Operations

Department of the Interior

Mr. Eric Beecroft, Special Assistant to the Secretary
Dr. Hilary J. Deason, Fish and Wildlife Service
Mr. Elmer Higgins, Chief, Division of Fishery Biology
Dr. John H. Provinse, Office of Indian Affairs
Mr. Oliver C. Ralston, Bureau of Mines

Department of Agriculture

Dr. W. V. Lambert, Assistant Research Administrator
Dr. P. N. Annand, Chief, Bureau of Entomology and Plant Quarantine
Mr. Elmer W. Brandes, Agricultural Research Administration, Plant Industry, Soils, and Agricultural Engineering
Dr. Eric Englund, Chief, Regional Investigations Branch
Mr. David G. Hall, Bureau of Entomology
Dr. J. T. Jardine, Chief, Office of Experiment Stations
Dr. C. E. Kellogg, Head, Division of Soil Survey, Plant Industry, Soils, and Agricultural Engineering

Department of Commerce

Rear Admiral Leo O. Colbert, Director, Coast and Geodetic Survey
Dr. Herbert Grove Dorsey, Coast and Geodetic Survey
Dr. E. C. McKay, Coast and Geodetic Survey
Lieutenant Commander W. M. Scaife, Coast and Geodetic Survey
Lieutenant Commander A. N. Stewart, Coast and Geodetic Survey
Dr. Francis W. Reichelderfer, Chief, U. S. Weather Bureau
Lieutenant Commander E. B. Roberts, Coast and Geodetic Survey
Dr. D. B. Robinson, Coast and Geodetic Survey

Children's Bureau, Department of Labor

Dr. Katherine Bain, Director, Division of Research in Child Development

United States Commercial Company

Dr. G. R. Parker, Chief, Pacific Ocean Division
Mr. H. E. Bishop, Assistant Chief, Pacific Ocean Division

United States Office of Education

Mr. C. O. Arndt, Division of International Educational Relations

United States Public Health Service

Dr. W. H. Wright, Scientist Director
Dr. Gilbert L. Dunnahoo, Chief, Foreign Quarantine Division

Smithsonian Institution

Dr. Alexander Wetmore, Secretary

American Council of Learned Societies

Mr. Mortimer Graves, Administrative Secretary

American Council on Education

Dr. A. J. Brumbaugh, Vice President

Social Science Research Council

Dr. Robert B. Hall, Chairman, Joint Exploratory Committee on World Area Research

SPECIAL GUESTS

The following foundations with an interest in Pacific research sent representatives to the Conference:

Mr. Neilson Abeel, Pacific War Memorial Foundation
Mr. Marshall Chadwell and Dr. Paul F. Russell, Rockefeller Foundation
Dr. Paul Fejos, Viking Fund, Inc.
Dr. Elmer D. Merrill, John Simon Guggenheim Memorial Foundation
Dr. W. A. Nyland, Coolidge Foundation
Mr. John M. Russell, John and Mary R. Markle Foundation
Dr. H. M. Weaver, National Foundation for Infantile Paralysis, Inc.

National Research Council

Membership and Organization.—The National Research Council is a cooperative organization of scientific men of America, including also a representation of men of affairs interested in engineering and industry and in the basic sciences upon which the applications of science depend. Its membership is largely composed of accredited representatives of about eighty-five national scientific and technical societies. Its essential purpose is the promotion of scientific research and of the application and dissemination of scientific knowledge for the benefit of the national strength and well-being.

The Council was established at the request of the President of the United States, by the National Academy of Sciences, under its Congressional charter to coordinate the research facilities of the country for work on military problems involving scientific knowledge. In 1918, by Executive Order, it was reorganized as a permanent body for the general encouragement of scientific research.

BULLETIN
OF THE
NATIONAL RESEARCH COUNCIL
Number 116 June 1948

INVESTIGATIONS OF HUMAN REQUIREMENTS FOR B-COMPLEX VITAMINS

Published by the National Research Council
National Academy of Sciences
Washington, D. C.

price $1.00

Announcement Concerning Publications
of the
National Research Council

The Proceedings of the National Academy of Sciences

is partly supported by the National Research Council which is represented officially on its Editorial Board and Executive Committee. It is open for the publication of papers to members of the National Research Council on the same terms as to members of the National Academy of Sciences.

Subscription rate for the *Proceedings* is $5 per year. Business address: Home Secretary, National Academy of Sciences, 2101 Constitution Ave., Washington 25, D. C.

The Bulletin of the National Research Council

present monographs especially prepared by Committees of the Council or directories for general use in science compiled by the Council.

The *Bulletin* is published at irregular intervals. A discount of 20% from the list price of the *Bulletins* will be given to all who subscribe for the Series as issued, direct from the Publication Office. Numbers of the *Bulletin* are sold separately at prices based upon the cost of manufacture.

The Reprint and Circular Series of the National Research Council

renders available for purchase, at prices dependent upon the cost of manufacture, papers published or printed by or for the National Research Council. A discount of 20% from the list price will be given to all who subscribe for the Series as issued, direct from the Publication Office.

Orders for the *Bulletin* or the *Reprints and Circulars* of the National Research Council, accompanied by remittance made payable to the National Academy of Sciences, should be addressed: Publication Office, National Research Council, 2101 Constitution Ave., Washington 25, D. C.

A list of publications of the National Research Council with prices will be furnished upon request.

BULLETIN
OF THE
NATIONAL RESEARCH COUNCIL
NUMBER 116 JUNE 1948

INVESTIGATIONS OF HUMAN REQUIREMENTS FOR B-COMPLEX VITAMINS

By
MAX K. HORWITT, ERICH LIEBERT,
OSCAR KREISLER, AND PHYLLIS WITTMAN
With the supervision of the
Committee on Nutritional Aspects of Ageing
Food and Nutrition Board
Division of Biology and Agriculture

PUBLISHED BY THE NATIONAL RESEARCH COUNCIL
NATIONAL ACADEMY OF SCIENCES
WASHINGTON, D. C.

DEDICATION

This volume is dedicated to the memory of Doctor Charles F. Read who so wholeheartedly cooperated in the program and made this work possible, and whose vision and enthusiasm gave encouragement to everyone directly or indirectly connected with the program.

PREFACE

Studies of human requirements for B complex vitamins, which bear on nutritional aspects of ageing and on the significance of vitamin adequacy to mental health, are reported in this monograph by members of the staff of the Elgin State Hospital. These studies were undertaken at the suggestion of the chairman of the Division of Biology and Agriculture of the National Research Council, Dr. Robert F. Griggs, and were conducted under the supervision and guidance of the Committee on the Nutritional Aspects of Ageing of the Food and Nutrition Board. The membership of this committee was as follows:

E. S. Guzman Barron, M.D., University of Chicago
Conrad A. Elvehjem, Ph.D., University of Wisconsin
A. Baird Hastings, Ph. D., Harvard University
Max K. Horwitt, Ph. D., Elgin State Hospital and University of Illinois, Director of the Biochemical Research Laboratory
Erich Liebert, M.D., Elgin State Hospital and Northwestern University
Wm. deB. MacNider, M.D., University of North Carolina
Charles F. Read, M.D.,[1] Superintendent Elgin State Hospital
Lydia J. Roberts, Ph. D., University of Chicago, succeeded by—
Tom D. Spies, M.D., Hillman Hospital, Birmingham, Alabama and University of Cincinnati
Ray D. Williams, M.D., Vice-chairman of the committee, Washington University, St. Louis
Russell M. Wilder, M.D., Chairman of the committee, Mayo Clinic, Rochester, Minnesota

Members ex-officio were:

Robert F. Griggs, Ph.D., Chairman Division of Biology and Agriculture, National Research Council
Frank G. Boudreau, M.D., Chairman Food and Nutrition Board and Director Milbank Memorial Fund
Frank L. Gunderson, Ph. D., succeeded by Paul Pavcek, Ph.D., Executive Secretaries Food and Nutrition Board
Frank Fremont-Smith, M.D., Medical Director, Josiah Macy, Jr. Foundation

The investigators and the committee gratefully acknowledge advice and counsel sought from time to time from Dr. Ancel Keys of the University of Minnesota, Dr. H. D. Kruse of the Milbank Memorial Fund, Dr. T. E. Friedemann of Northwestern University, Drs. W. H. Welker and Olaf Bergeim of the University of Illinois, and Dr. R. W. Gerard of the University of Chicago, and the active cooperation accorded by Dr. D. Louis Steinberg who in 1946 succeeded Dr. Read as superintendent of the Elgin State Hospital.

The static nature of the patient population of hospitals devoted to the care of the mentally ill affords opportunities less commonly available in general hospitals for studies of metabolism which require unusually long-continued maintenance of special diets and reliable collection of biological specimens. Research conducted in these institutions opens doors for cooperative efforts in the common interest on the part of administrative officers, hospital staffs and patients. Furthermore, the contribution of the patient can be one of usefulness, not alone to the study in which he is engaged as a subject, but to his personal welfare.

---

[1] Deceased March 11, 1946.

Investigation such as that reported here, conducted with the consent not only of the patient but likewise of his legal guardian and under suitably rigid medical supervision, warrants more encouragement and support than has been given heretofore. The policy of mental institutions to provide custodial care and little else is being challenged sharply, a challenge which can be met effectively only by endeavors to dispel the cloud of ignorance that prevents more satisfactory treatment of the mentally infirm. Appreciation of the situation prompted Dr. Charles F. Read, late superintendent of the Elgin State Hospital, to organize a biological research laboratory in that institution. It led, moreover, to his sponsoring the research project on nutrition here reported. It is deeply to be regretted that Dr. Read did not survive to see the project through to its conclusion. The sincerity of his interest in it, his industry and his administrative talent contributed importantly to its successful outcome.

When compared with the expense of research involving animals, the cost of long-term studies of human nutrition is tremendous. The difference, however, is mainly comprehended in the cost of maintenance of human subjects, the cost of their custodial care, which when they are housed in an institution is not to be avoided under any circumstances. However, in the project here reported, the State of Illinois, through its Department of Public Welfare, assumed not only custodial costs but much of the expense of the personnel, materials, equipment and facilities of the project. The generous support of the Director and Deputy Director of the Department of Public Welfare was a source of great encouragement to the Elgin group of workers and to its advisory committee. For other necessary funds grateful acknowledgment is made to the Josiah Macy, Jr. Foundation and the Milbank Memorial Fund.

Several departments of the Elgin State Hospital assisted in this study. The entire staff of the Biochemical Research Laboratory was engaged. The clinical, pathological and psychological departments gave freely of the time of their respective staffs. The department of dietetics provided dietitians and cooks. Nurses and attendants were made available. For this assistance the investigators and the committee are truly grateful. Special appreciative acknowledgment is made to the dietitians, Miss Eleanor Gundlach and Miss Gordon Sampson, to the laboratory associates and assistants, Dr. C. C. Harvey, Mr. Henry Tigerman, Mrs. Blanche Tigerman, Mr. William S. Brown, Miss A. Ringgold and Mr. W. Young, to other assistants including Mrs. Edna Newtson, Mr. Paul Riggs and Miss Charlotte Kaplan, and to the nurses and attendants. Last but not least to be acknowledged by the investigators and the committee is the contribution of the patients who served as subjects of investigation for the three successive years of the duration of the study.

RUSSELL M. WILDER.

TABLE OF CONTENTS

PAGE

INTRODUCTION 1
SECTION I: Description of Procedure. *Max K. Horwitt, Ph.D.* 3
SECTION II: Biochemical Observations. *Max K. Horwitt, Ph.D.* 12
SECTION III: Clinical Observations. *Oscar Kreisler, M.D.* 47
SECTION IV: Neurological Observations. *Erich Liebert, M.D.* 76
SECTION V: Psychological Observations. *Phyllis Wittman, Ph.D.* 89
SUMMARY AND GENERAL CONCLUSIONS: *Ray D. Williams, M.D., E. S. Guzman Barron, M.D., Conrad A. Elvehjem, Ph.D. and Max K. Horwitt, Ph.D.* 100

INTRODUCTION

From June 1943 to August 1946 a group of mental patients was continuously maintained on a predetermined diet designed to be only slightly less than adequate with respect to thiamine and riboflavin. Another group of mental patients, serving for control, was given the same diet supplemented with a yeast extract which provided a liberal supply of the vitamins in question. The control group of subjects, after two years on this regime, was placed on a diet which provided an amount of thiamine known to be inadequate. At the same time the yeast extract was withdrawn. In the end both groups of subjects were restored to fully adequate regimens. The study was undertaken to ascertain the minimal requirements for thiamine and riboflavin of older versus younger men, with reference in particular to the influence of low and high intakes of these vitamins on mental disease. Comparable earlier research, both on animals and with human subjects, as well as earlier clinical observations of patients who spontaneously had developed deficiencies of these vitamins, provided information which permitted restriction of the vitamins in question to levels at which any resulting manifestations of deficiency, if treated in time, would be reversible and hence without permanent ill effect. The patients, although mentally infirm, were physically in reasonably good health. They volunteered to serve as subjects, but in every instance the approval of the guardian and family also was obtained.

In the plan originally designed by the committee the daily allowances of thiamine and riboflavin were to be reduced to 400 and 800 micrograms, respectively, with the group of control subjects receiving the same diet supplemented with crystalline thiamine and riboflavin. Deficiencies other than those attributable to an inadequate supply of thiamine and riboflavin were not at first considered. Later it seemed that the possibility of deficiency developing from lack of some other possibly unknown factor of the vitamin B complex could not be ignored in diets composed wholly of foods low in thiamine and riboflavin. Therefore the committee early advised adding the entire vitamin B complex to the diets of the group of subjects who were serving as controls. For this purpose yeast extract was given. In other respects the diet of the subjects restricted as to thiamine and riboflavin was identical to that of the control group. The food itself supplied calories and amino acids in adequate amounts, and vitamins A and D, ascorbic acid, iron, and calcium were administered as supplements both to experimental subjects and to controls.

At the end of the second year of the experiment the subjects whose intakes of thiamine and riboflavin were 400 and 800 micrograms, respectively, showed no incontrovertible alteration of their clinical state. However, some of the investigators suspected mild clinical abnormalities, and the biochemists in particular, noting differences in response to metabolic loads, between the subjects on the depleted diets and the controls, were convinced that abnormality existed which could be attributed to deficiencies. It was to throw light on this question that the subjects receiving the yeast extract and those serving as controls were placed on diets which contained only 200 micrograms of thiamine. At the same time the yeast extract was withdrawn. In a few months marked abnormalities, both clinical and biochemical, developed in these subjects, which substantiated the validity of the less striking changes observed in the group of subjects who obtained 400 micrograms of thiamine from their diets. Additional confirmatory evidence of the significance of the earlier observations was ultimately provided by the favorable response of both groups of subjects to treatment, in some cases with crystalline thiamine, in others with yeast extract.

The results of this experiment indicate that lack of thiamine may provoke marked aggravation of mental abnormality, but that the change so effected can be reversed, if taken in time, by giving thiamine. The results do not provide conclusive evidence for an earlier assumption that requirements for thiamine are increased by ageing. They give no conclusive evidence as to minimal requirements of either the young or the aged for riboflavin.

Despite the inconclusive nature of the evidence as to effects of age on requirements for thiamine and other members of the B complex group of vitamins, the data constitute a contribution of significance to the science of nutrition. These data are presented by the several investigators with a minimum of interpretation. However, it is the hope of the committee that the desirability of further interpretation and thoughtful speculation will not be neglected, and that the investigators, in separate publications in the scientific periodicals of the several disciplines involved, will elaborate on the brief discussion of the material provided in this monograph.

SECTION I

DESCRIPTION OF PROCEDURE

Max K. Horwitt, Ph.D.

Plan of study.—Stephenson, Penton and Korenchevsky[1] reported improvement of the mental and physical health of patients in an English mental institution when thiamine and ascorbic acid were administered. This report stimulated many students of geriatrics and prompted the project here reported. The original intention was to compare over a period of years the effects of liberal versus moderately restricted allowances of B complex vitamins on the mental and physical status of mental patients, when other factors of the diet and environment were kept relatively constant. After a period of two years the absence of striking differences prompted modification of the plan of study. The patients whose diets had theretofore been supplemented with yeast extract, and who thus had been liberally supplied with B complex vitamins, were now subjected to severe restriction with respect to B complex vitamins, while the patients on moderately restricted allowances of these vitamins were continued on the same moderate restriction. A corollary of the original plan of study was to determine the effects of age on resistance or susceptibility to adverse dietary conditions. Therefore, the groupings of the patients were so arranged that both old and young persons simultaneously would be subjected, on the one hand, to restriction of B complex vitamins and, on the other, to a liberal allowance of these vitamins.

Selection and grouping of subjects.—The facilities available for this investigation limited the choice of subjects to male patients, of whom at the time there were 2,500 in the hospital. Selection was based on the following criteria:

1. The patient should have been in the hospital for at least one year, with continued confinement for an additional two years anticipated.
2. He should be free from serious physical abnormality or disease. Also the record of his general resistance to intercurrent infections should be good.
3. He should be cooperative and not subject to periods of excitement or outbursts of anger.
4. His guardian and family must approve of his cooperation as a subject.
5. His age as an older subject should be between 60 and 80; as a younger subject between 20 and 40.

It proved exceedingly difficult to obtain subjects who could fully meet all these requirements and certain concessions had to be made, namely, several old patients with mild hypertension but without cardiac or renal damage were admitted, and for young subjects it was not possible to exclude some patients who occasionally were disturbed. The selections for the most part were fortunate, for only one elderly subject had to be excluded later. The young subjects were rather passive and with them tests which required active cooperation, such as psychological testing, could not be performed satisfactorily. One elderly subject developed a benign tumor of the rectum requiring operation and another developed a hernia requiring repair.

However, both of these men could continue the experimental regimen while confined to the infirmary.

TABLE 1

CODE NUMBER AND STATISTICAL DATA OF SUBJECTS AS OF APRIL 1943

GROUP A				GROUP B				GROUP C			
Subject	Age	Wt.	Ht.	Subject	Age	Wt.	Ht.	Subject	Age	Wt.	Ht.
		kg.	*cm.*			*kg.*	*cm.*			*kg.*	*cm.*
AY1	34	61	170	BY1	42	58	158	CY1	24	68	178
AY2	35	67	178	BY2	28	60	172	CY2	33	60	180
AY3	37	73	174	BY3	34	56	166	CY3	26	54	156
AY4	31	53	164	BY4	26	53	168	CY4	23	76	178
AY5	24	56	172	BY5	28	52	175	CY5	29	59	165
								CY6	23	48	159
								CY7	17	64	170
								CY8	26	57	168
AO1	66	50	160	BO1	69	64	166	CO1	69	56	185
AO2	74	71	178	BO2	60	59	176	CO2	78	58	156
AO3	71	72	176	BO3	64	60	156	CO3	71	64	178
AO4	69	73	170	BO4	76	66	158	CO4	77	64	170
AO5	68	84	175	BO5	58	60	169	CO5	72	93	168
AO6	68	65	160	BO6	63	73	165	CO6	72	96	160
AO7	74	63	163	BO7	79	67	165	CO7	55	109	178

TABLE 2

DIET A

Menu 1

FOOD	STATE OF PREPARATION	AMT.	CHO	PROT.	FAT	CALORIES
		gms.	*gms.*	*gms.*	*gms.*	
Bread	Unenriched	200	88.8	12.6	2.8	431
Oleomargarine	Vitamin A Fortified	45	—	—	36.5	329
40% Cream	As purchased	50	1.7	1.1	20	191
Meat, Beef	Roasted	100	—	30.0	6.0	174
Potato	Baked	100	19.1	2.0	—	84
Sugar	As purchased	40	40	—	—	160
Grape Jelly	Home canned	45	29.2	—	—	117
Spaghetti or Macaroni (dry)	Boiled	50	36.9	6.5	0.7	180
Corn Flakes	Unenriched	30	24.1	2.4	—	106
Peaches	Home canned	100	21.0	0.4	0.1	87
Carrots	Cooked	80	6.1	0.8	—	28
Tomatoes	Home canned	50	3.9	0.5	—	20
Cake	Spec. recipe	65	40.7	2.9	9.5	260
Totals			311.5	59.7	75.5	2167

Twenty-one elderly subjects and nineteen young subjects were finally chosen and housed in an isolated building, Wing Cottage. There, in November 1942 they were re-examined and observed until June 1943, the time of the beginning of the research period. They were then divided into the following dietary groups: A, B and C, each consisting of old and young men. Table 1 gives their ages, weights, and heights.

Group A, consisting of a subgroup of five young men whose ages ranged from 24 to 37 years and a subgroup of seven old men whose ages ranged from 66 to 74 years, received the standardized diet (Tables 2, 3 and 4) known to contain 2,200 calories, 400 milligrams of thiamine, and 800 milligrams of riboflavin. These subgroups were called the AY and AO groups, respectively.

TABLE 3
DIET A
Menu 2

FOOD	STATE OF PREPARATION	AMT.	CHO	PROT.	FAT	CALORIES
		gms.	*gms.*	*gms.*	*gms.*	
Bread	Unenriched	200	88.8	12.6	2.8	431
Oleomargarine	Vitamin A Fortified	55	—	—	44.6	401
40% Cream	As purchased	50	1.7	1.1	20.0	191
Meat, Beef	Roasted	100	—	30.0	6.0	174
Sugar	As purchased	40	40.0	—	—	160
Potato	Baked	100	19.1	2.0	—	84
Corn sugar	As purchased	36	36.0	—	—	144
Rice (polished)	Boiled	(dry) 50	39.7	3.8	—	174
Farina	Unenriched	30	22.8	3.5	0.3	108
Beets	Boiled	100	6.0	2.0	—	32
Cabbage	Boiled	50	2.7	0.7	—	14
Jello	34% solution	34	30.0	3.2	—	133
Prunes	Stewed	50	35.5	1.2	—	147
Totals			322.3	60.1	73.7	2193

Group B, consisting of a subgroup of five young men whose ages ranged from 26 to 42 years and a subgroup of seven old men whose ages ranged from 58 to 79 years, received the standardized diet provided for the A group, supplemented with an extract of brewer's yeast. The composition of the extract is given (Table 5).

Group C, consisting of eight young men whose ages ranged between 17 and 33 years and seven old men whose ages ranged between 55 and 78 years, were allowed free access to the general hospital diet* served in a separate building not far from Wing Cottage. Wherever young and old subjects are considered separately in the text, subgroups are designated by the addition of the letters Y and O to the letters A, B, or C. Thus CY represents the young subjects of Group C, CO the old subjects of Group C, and so forth. Individual subjects are numbered consecutively in each of these subgroups; thus, for example, AY1, AY2, and AY3 designate individuals in subgroup AY.

---

* The hospital diet provided approximately 2,500 calories, 1 mg. of thiamine, and 1.5 mg. of riboflavin.

All subjects of groups A and B received the following vitamin and mineral supplements:† vitamin A 5,000 I.U.; vitamin D 400 I.U.; ferrous sulfate 0.2 gm.; dicalcium phosphate 1.5 gm.; and ascorbic acid 75 mg., daily. The 6 grams of yeast extract given to the subjects of group B provided not less than 3.6 mg. of thiamine and 2.3 mg. of riboflavin per day. The subjects of group A received a placebo resembling this yeast extract. The subjects of group C, eating the general hospital diet, received no supplements of vitamins or minerals.

TABLE 4

DIET A

Menu 3

FOOD	STATE OF PREPARATION	AMT	CHO	PROT.	FAT	CALORIES
		gms.	gms.	gms.	gms.	
Bread	Unenriched	200	88.8	12.6	2.6	431
Oleomargarine	Vitamin A Fortified	45	—	—	36.5	329
40% Cream	As purchased	50	1.7	1.1	20.0	191
Meat, Beef	Roasted	75	—	22.5	4.5	131
Sugar	As purchased	30	30.0	—	—	120
Potato	Baked	100	19.1	2.0	—	85
Spaghetti or Macaroni	Boiled	(dry) 50	36.9	6.5	0.7	180
Corn Flakes	As purchased	30	24.1	2.4	—	106
Tomatoes	Canned	50	2.0	0.5	—	10
Apple Sauce	Water packed	100	10.9	0.2	0.2	46
Cottage Cheese	Dry skim	50	4.3	9.6	0.4	59
Jelly	Home canned	45	29.3	—	—	117
Corn	Canned	80	15.7	2.0	0.7	77
Cookies	Spec. recipe	75	49.7	3.8	14.0	341
Totals			312.5	63.2	79.6	2223

TABLE 5

ANALYSIS OF YEAST EXTRACT

Protein	50.2%
Moisture	2.5%
Thiamine	0.9 mg. per gm.
Pyridoxine	0.1 mg. per gm.
Calcium Pantothenate	0.5 mg. per gm.
Inositol	2.98 mg. per gm.
Riboflavin	0.24 mg. per gm.
Niacin	1.7–2.0 mg. per gm.
Biotin	0.001 mg. per gm.

---

† We are indebted to Hoffmann-LaRoche, Inc. for the vitamin A and D tablets, to Smith, Kline and French, Inc. for the ferrous sulfate, and to Merck and Co., Inc. for the ascorbic acid, thiamine, and riboflavin tablets. Standard Brands, Inc. donated the yeast extract, for which thanks are expressed to that company and to its laboratory director, Dr. Charles N. Frey.

Preparation, serving, and analysis of diet.—The preparation and serving of the food was closely supervised by a trained dietitian, two cooks and an attendant. Samples of about one-half of all the meals fed were analyzed for their contents of thiamine and riboflavin. All of the bread was made with unenriched white flour. During the last two years of the work, as an additional check, the bread was analyzed every day in order to eliminate the possibility of introduction of flour fortified with vitamins. The records show no single high thiamine or high riboflavin analysis in that time. A few earlier analyses of sample meals which indicated small increases in thiamine content could possibly have been analytical errors, since the content of riboflavin was not correspondingly increased on the days in question.

Tables 2, 3, and 4 present illustrations of the foods in typical menus for Group A for three years, for Group B for the first two years of dietary control, with calculations of protein, fat, carbohydrate, and calories. The use of three menus rather than one permitted greater variety in the appearance of the food. This is an important factor when subjects remain on a controlled diet for long periods of time.

During the early use of the experimental diet each food was weighed before and after cooking. After about ten weeks, a large amount of data on cooked weights had accumulated to show that the technic of cooking was fairly constant and that cooked weights could be used regularly for serving rice, macaroni, sphaghetti, prunes, and fried potatoes. Casserole dishes were prepared individually to eliminate the possibility of variations in the homogeneity of servings. The meat was thoroughly roasted to destroy most of the thiamine by means of heat and oxidation. It was then either ground or cut into small units and mixed before serving. The rice was thoroughly washed before and after cooking to eliminate most of the thiamine present.

Because the individual subjects required different caloric intakes, many of the trays prepared were not interchangeable. Using the amounts shown in Tables 2, 3, and 4 as 100 per cent, the men received 80, 90, 100, or 110 per cent of these amounts, depending on size and average appetite. Food not consumed was weighed back and recorded.

After two years (from June 1943 to June 1945) the subjects in the B group, that is, those whose diets had been supplemented with yeast extract, were placed on a diet which contained only half as much thiamine, the yeast extract being withdrawn. The intake of riboflavin remained approximately what it had been. The reduction of thiamine was accomplished by substituting rice for all potatoes and sphaghetti, and by serving biscuits instead of loaf bread. The same low-thiamine flour produced a biscuit product which contained only about one-third as much thiamine as loaf bread. A preliminary study indicated that loss of thiamine in baking was caused by reduction of the size of the unit baked and not by the use of baking powder as in the preparation of biscuits. Tables 6, 7, and 8 present the components of the three menus served to the subjects of the B group in order to effect more severe restriction of thiamine during the third year of the project.

When a feeding or behavior problem did not yield readily to treatment by the dietetic personnel, the problem was at once called to the attention of one of the clinicians. For example, one of the younger unsupplemented subjects refused to eat at all for a few days and had to be tube fed. On another occasion one of the older unsupplemented men drank a portion of a yeast extract supplement. His stomach was pumped immediately.

The values used for calculation of the thiamine and riboflavin consumed were obtained by analysis of sample meals. Each sample was collected in a rectangular glass-covered refrigerator dish. This dish was transported from the diet kitchen to the analytical laboratory where the contents, transferred to a Waring blendor, were ground until homogeneous. The beverage taken with the meal and 5 ml. of glacial acetic acid plus a little water were added to facilitate mixing in the blendor. The homogenized mixture was poured into a glass-covered tared dish which was placed in the freezing unit of the refrigerator. The Waring blendor receptacle was also placed in the refrigerator until the next meal, when the process was repeated. After three meals had been homogenized and the contents of the Waring blendor completely transferred to the glass-covered dish, the dish and contents were weighed accurately to within one gram. Then the contents were thoroughly mixed by hand for five minutes. Twenty heaping teaspoonfuls of this mixture taken from different parts of the container were transferred to a 400 ml. beaker and the contents of the beaker were stirred for a full minute. This was transferred to a 4 oz. sample bottle, placed in a deep freeze refrigerator, and analyzed within a week.

TABLE 6
DIET B
Menu 1

FOOD	STATE OF PREPARATION	AMT.	CHO	PROT.	FAT	CALORIES
		gms.	*gms.*	*gms.*	*gms.*	
Biscuits	Spec. recipe	160	68.0	11.9	14.0	446
Oleomargarine	Vitamin A Fortified	45	—	—	36.5	329
40% Cream	As purchased	50	1.7	1.1	20.0	191
Beef	Roast (round)	100	—	30.0	6.0	174
Rice (polished)	Boiled	100	79.4	7.6	—	348
Sugar	As purchased	40	40.0	—	—	160
Grape Jelly	Commercial	45	29.2	—	—	117
Corn Flakes	Unenriched	30	24.1	2.4	—	106
Carrots	Home canned	80	6.1	0.8	—	28
Peaches	Home canned	100	21.0	0.4	0.1	87
Tomatoes	Home canned	50	2.0	0.5	—	10
Rhubarb	Home canned	100	42.0	0.5	0.1	174
Cake	Spec. recipe	65	40.7	2.9	9.5	260
Totals			354.2	58.1	86.2	2428

The method for analysis of thiamine was essentially that of Conner and Straub.[2] The microbiological procedure of Snell and Strong[3] was used, with some modification, for determining riboflavin. The yeast extract was analyzed from time to time for thiamine and riboflavin. The sample meals for analyses were subjected to the

TABLE 7

DIET B

Menu 2

FOOD	STATE OF PREPARATION	AMT.	CHO	PROT.	FAT	CALORIES
		gms.	gms.	gms.	gms.	
Biscuits	Spec. recipe	160	68.0	11.9	14.0	446
Oleomargarine	Vitamin A Fortified	45	—	—	36.5	329
40% Cream	As purchased	50	1.7	1.1	20.0	191
Beef	Roast (round)	100	—	30.0	6.0	174
Sugar	As purchased	40	40.0	—	—	160
Jelly	Commercial	45	29.2	—	—	117
Rice (polished)	Boiled	100	79.4	7.6	—	348
Farina	Unenriched	30	22.8	3.5	0.3	108
Tomatoes	Home canned	50	2.0	0.5	—	10
Cabbage	Boiled	50	2.7	0.7	—	14
Jello	34% solution	34	30.0	3.2	—	133
Rhubarb	Home canned	100	42.0	0.5	0.1	174
Apple Sauce	Water packed	100	10.9	0.2	0.2	46
Totals			328.7	59.2	77.1	2250

TABLE 8

DIET B

Menu 3

FOOD	STATE OF PREPARATION	AMT.	CHO	PROT.	FAT	CALORIES
		gms.	gms.	gms.	gms.	
Biscuits	Spec. recipe	160	68.0	11.9	14.0	446
Oleomargarine	Vitamin A Fortified	45	—	—	36.5	329
40% Cream	As purchased	50	1.7	1.1	20.0	191
Beef	Roast (round)	75	—	22.5	4.5	131
Sugar	As purchased	30	30.0	—	—	120
Rice (polished)	Boiled	100	79.4	7.6	—	348
Corn Flakes	Unenriched	30	24.1	2.4	—	106
Tomatoes	Home canned	50	2.0	0.5	—	10
Apple Sauce	Water packed	100	10.9	0.2	0.2	46
Cottage Cheese	Dry skim	50	4.3	9.6	0.4	59
Corn	Home canned	80	15.7	2.0	0.7	77
Jelly	Commercial	45	29.2	—	—	167
Rhubarb	Home canned	100	42.0	0.5	0.1	174
Cookies		75	49.7	3.8	14.0	341
Totals			357.0	62.1	90.4	2545

same conditions as the meals consumed by the subjects, that is the cooking, stirring, and exposure incidental to the time taken to get the meal to the subject were the same.

The analyses of 383 composite daily samples of the depletion diet of the A group subjects showed the average total daily intake of thiamine on the basal diet of 2,200 calories to be 413 micrograms, or 188 micrograms per 1,000 calories. Similar analyses of 373 composite samples of the diet for riboflavin showed that it provided an average of 807 micrograms of riboflavin, or 367 micrograms per 1,000 calories. The nicotinic acid and pantothenic acid contents of the diet were determined microbiologically.[4, 5] They were 13.2 and 3.8 milligrams, respectively. The ascorbic acid content of the diet was less than 15 milligrams, which, however, was increased by the 75 milligrams of ascorbic acid given daily. Amino acid analysis of the diet revealed an adequate coverage of all the essential amino acids.

The severely restricted diet used in 1945 and 1946 for the B group was also analyzed as above. It provided an average of 203 micrograms of thiamine and 749 micrograms of riboflavin (96 and 84 composite samples, respectively). Therefore, since the caloric intake on this diet remained approximately the same (2,200 calories) these subjects obtained about one-half as much thiamine as did the A group subjects during their depletion period. The nicotinic acid and pantothenic acid contents of this diet were 9.0 and 3.1 milligrams per day, respectively. As before, the amino acid coverage was adequate.

Physical arrangements.—Wing Cottage, a two story building with a basement that was converted into a well-equipped diet kitchen and two separate dining rooms, was utilized to house all subjects. Several rooms on the upper floors were set aside as offices and examination rooms for the attending physicians. The hospital pathological laboratory occupied two rooms of the first floor. Also on the first floor were bed facilities for approximately twenty-four subjects. The Biochemical Research Laboratory occupied four rooms on the second floor. Additional space on the second floor provided for approximately twenty beds equally divided between two roomy dormitories. One smaller room had space for three beds and this was used to isolate subjects who developed intercurrent illnesses. The examining room for the clinician in residence was also on this floor. A dumb-waiter connecting the upper floors with the diet kitchen facilitated food service to isolated patients.

Because of war-time shortages, early plans to move the laboratories to a separate building reconstructed to serve as a research unit did not materialize until after the project had been in progress for about two years. When the laboratories were moved to their new quarters additional space in Wing Cottage was made available for the use of the subjects of the experiment.

General comments.—The subjects who were on rigid dietary control (Groups A and B) did not leave the ward even in the company of their relatives except for supervised recreation in the presence of an attendant. The group C subjects ate in the general dining room and were unrestricted as to food consumption.

Reversal of deficiency regimens to regimens high in thiamine and riboflavin was at all times subject to the judgment of the clinician in attendance, in accordance with the general policy that the health of the patient took precedence over all other considerations.

REFERENCES

1. STEPHENSON, W., PENTON, C. AND KORENCHEVSKY, V.: Some effects of vitamin B and C on senile patients. Brit. Med. J. 839–844 (Dec.) 1941. (2).

2. Conner, R. T. and Straub, G. J.: Determination of thiamine by the thiochrome method. Ind. Eng. Chem., Anal. Ed. *13:* 380–384, 1941.
3. Snell, E. E. and Strong, F. M.: A microbiological assay for riboflavin. Ind. Eng. Chem., Anal. Ed. *11:* 346–350, 1939.
4. Krehl, W. A., Strong, F. M. and Elvehjem, C. A.: Determination of nicotinic acid. Modifications in microbiological method. Ind. Eng. Chem., Anal. Ed. *15:* 471–475, 1943.
5. Ives, M., Zepplin, M., Ames, S. R., Strong, F. M. and Elvehjem, C. A.: Nutritional values of canned foods. X. Further studies of riboflavin, niacin and pantothenic acid. J. Am. Dietetic Assoc. *21:* 357–359, 1945.

SECTION II

BIOCHEMICAL OBSERVATIONS

Max K. Horwitt, Ph.D.

Numerous investigations have shown that in thiamine deficiency there are certain changes in carbohydrate metabolism which can be of diagnostic value, changes which occur in consequence of the role of diphosphothiamine as a coenzyme. In fact, even before Lohmann and Schuster (1) discovered that cocarboxylase was the pyrophosphate ester of thiamine, Thompson and Johnson (2) had shown that pyruvate accumulates in the blood of animals in experimental vitamin B deficiency. Similar pyruvate increase in the blood of men with beriberi was demonstrated by Platt and Lu (3). Barron and his coworkers (4, 5) have further shown that diphosphothiamine is a coenzyme not only for the oxidation, decarboxylation, dismutation, and condensation processes of pyruvate, but for the oxidation of alpha ketoglutarate as well.

The accumulation of pyruvate in the blood and other tissues under conditions where cocarboxylase is decreased can be very striking. The rapid reversibility of acute thiamine deficiency in pigeons in which the characteristic opisthotonos occurs before any definite neurological lesion can be observed suggests that pyruvate breakdown is associated with nerve function. The work of Mann and Quastel (6), showing that pyruvate oxidation is necessary for the synthesis of acetylcholine in brain tissue, further indicated the possibility that the neurological manifestations of beriberi are associated with a biochemical disturbance of carbohydrate metabolism.

While it has been known for some time that blood lactate levels increase after exercise (7) and during anoxia (8, 9), it was not until recent years that elevation of blood pyruvate under similar conditions was associated with these changes (10, 11, 12). Now it is possible to consider together changes in lactate and pyruvate in muscle metabolism. Friedemann and Barborka (13) and Stotz and Bessey (14, 12) have shown that there is a definite ratio between levels of lactate and pyruvate in the blood. Stotz and Bessey advocated the use of blood lactate-pyruvate ratios to distinguish true abnormality of pyruvate metabolism from the fluctuations due to factors such as exercise, food consumption, and anoxia. They showed in pigeons that the use of the ratio in experimental thiamine deficiency made it possible for them to note disturbance of pyruvate metabolism in the early stages of thiamine deficiency.

As a result of the emphasis placed upon increases in pyruvic acid associated with thiamine deficiency there have been many clinical attempts to use the basal levels of pyruvic acid in the blood as an indication of the degree of thiamine deficiency of the patient. On the whole there has been no agreement between values of blood pyruvic acid and thiamine deficiency states. This discrepancy may be due either to variability of the basal level of the pyruvic acid, or to lack of agreement regarding the subclinical signs of thiamine deficiency, or to both reasons.

A comparison of the blood pyruvate curves obtained following glucose ingestion in normal and in thiamine-deficient subjects by Bueding, Stein, and Wortis (15) showed that the ingestion of glucose caused a temporary but significant elevation of blood pyruvic acid, which was abnormally prolonged and elevated in thiamine deficiency.

Williams, Mason, Smith, and Wilder (16) made similar observations. They attempted to use the level of pyruvic acid, as well as of lactic acid, in the diagnostic evaluation of thiamine deficiency. Similar results were obtained by these investigators, studying the levels of pyruvic acid and lactic acid after the administration of glucose.

It was the opinion of Williams and his coworkers (17) that the basal level of pyruvic acid was not as good an indication of thiamine deficiency as were those levels which were obtained after the administration of a "metabolic load" such as glucose or applied standardized exercise.

As a result of the investigations quoted above, it was decided to pay special attention to the lactate-pyruvate ratios and to the "metabolic load" of Williams and his coworkers as tests of subclinical nutritional deficiencies in the present study.

METHODS

The methods used to determine the amounts of glucose, lactic acid, and pyruvic acid in the blood were as follows:

1. *Glucose* was estimated according to the colorimetric method described by Hoffman (18) using a Coleman spectrophotometer at a wave length of 415 millimicrons.

2. The method used to determine *pyruvic acid* in the blood was essentially that described by Friedemann and Haugen (19), except that the pyruvic acid hydrazone was extracted with two 5 ml. portions of ethyl acetate instead of a single extraction with 8 ml. Spectrophotometric readings of the sodium hydroxide-treated hydrazone were made at a wave length of 520 millimicrons.

3. *Lactic acid* was determined according to the technic described by Barker and Summerson (20), except that (a) all solutions of trichloracetic acid used were filtered through sintered glass crucibles to remove traces of organic matter, which may precipitate when the 10 per cent solution of trichloracetic acid is prepared, and (b) the sulfuric acid used was prepared by mixing one liter of concentrated sulfuric acid with 116 ml. of water and 7 ml. of 4 per cent copper sulfate. This insured the presence of equal amounts of copper in each reaction tube. (c) The treatment of the blood filtrate with copper and calcium was eliminated, since a large number of analyses showed greater constancy of the results when this step was not used. The slightly higher results obtained when this step was omitted were within the limits of error of the procedure.

It should be recalled that no one of the above three methods is specific. This is especially true for the glucose determination, in which many other reducing substances are included in the analysis, and for the pyruvic acid method, which includes other keto-acids.

The data obtained, however, are quite valid for physiological interpretations. To insure as far as possible that these findings should be reproducible, it was a rule of this laboratory that at least two points on a standard curve be determined *every day* that a photometric method was used.

4. *Blood Collections:* The importance of speed and low temperatures in the collection of blood for the determination of lactic and pyruvic acids cannot be overemphasized. Friedemann and Haugen (19) have fully discussed this point.

5. *Urinary Analysis for Thiamine and Riboflavin:* The *thiamine method* of Hennessey and Cerecedo (21), with minor modifications to suit the Coleman photofluorometer, was used during the early phases of the study. The possibility that some of the fluorescence obtained was due to compounds other than thiochrome was evaluated with nearly all of the urine samples, but the non-thiochrome fluorescence was at no time sufficient to affect the interpretation of the data obtained (22).

6. The microbiological method of Snell and Strong (23) with minor modifications was used to determine the *riboflavin* content of the urine. The urea concentration of the urines of the subjects on the experimental diets was relatively small, and it was therefore possible to minimize the inhibitory effect of urea on the growth of *Lactobacillus casei*.

ORAL VS. INTRAVENOUS GLUCOSE TOLERANCE METHODS

In the spring of 1943, while the subjects were being observed to determine whether they were suitable for the work which was to follow, an attempt was made to evaluate the relative usefulness of intravenously versus orally administered glucose as metabolic loads to raise the levels of blood lactic and pyruvic acids.

For the *intravenous tests* 0.8 ml. of 50 per cent glucose was administered per kg. of body weight. Samples of blood were withdrawn before and 30, 60, and 120 minutes after injection. The tests of the oral administration of glucose were conducted about three weeks later, using 9 ml. of 20 per cent glucose for each kilogram of body weight. This provides 126 grams of glucose for an individual weighing 70 kilograms as compared to only 28 grams given intravenously to a subject of equal body weight. Samples of blood for testing the effects of the oral metabolic load were taken before and 60, 120, and 180 minutes after glucose ingestion.

During the preliminary period prior to the use of the depletion diets, 32 subjects were available for a comparative test of the relative value of intravenous versus oral administration of glucose. The results of these two series are given in Table 9.

This experience created the impression that the oral route of glucose administration would be the preferred technic for a long-term study involving possible changes in carbohydrate metabolism. The early doubts that the subjects would cooperate later proved unwarranted, since all swallowed the large amounts of glucose solution with few complaints. The convenience of a longer period of time between the first two blood collections, and the fact that a sterile glucose solution was not necessary, were advantages much appreciated during mornings when six or more patients were tested simultaneously. The necessity of having healthy veins for frequent blood withdrawals for the many tests scheduled was a further indication for the oral technic. Most important was the probability that a greater metabolic load could be given via the oral route.

These results gave evidence that the older individuals had an apparently retarded carbohydrate tolerance. The factor of absorption from the intestinal tract could be minimized as an important characteristic in prolonging the higher levels because slower utilization of carbohydrate was true of the intravenous, as well as of the oral, test.

The oral method of glucose administration described above was used without any changes for the first few months after the beginning of the depletion period (June 1943). Late in July 1943 attempts to study the effects of exercise were made in an effort to increase the amount of the metabolic load. In most cases the exercise (consisting of a standardized stair climbing test which will be described later) was applied 180 minutes after the administration of glucose, at which time the blood levels of glucose had returned to normal or near normal levels. Blood for the determination of lactic and pyruvic acid was withdrawn about one minute after the completion of the exercise. The results obtained proved to be of little value, mainly because insufficient time had been allowed for the diffusion of the metabolites from the tissues to the blood stream. This was shown by later work which proved that at least three minutes are required for the lactic and pyruvic acid to reach a maximum concentration in the circulating venous blood after exercise.

TABLE 9

COMPARISON OF AVERAGES OF DATA OBTAINED AFTER ADMINISTRATION OF INTRAVENOUS AND ORAL GLUCOSE (MG.% IN BLOOD)

MINUTES AFTER ADMINISTRATION	Method	OLD SUBJECTS (19)			YOUNG SUBJECTS (13)		
		Glucose	Lactic	Pyruvic	Glucose	Lactic	Pyruvic
0	I.V.	105 ±6.5	7.8 ±2.3	1.02 ±.20	106 ±6.8	7.4 ±1.5	1.02 ±.29
0	Oral	101 ±9.0	8.6 ±2.5	1.02 ±.26	102 ±6.0	7.7 ±1.7	1.06 ±.25
30	I.V.	184 ±38	11.6 ±2.4	1.38 ±.27	169 ±25	10.7 ±2.2	1.24 ±.20
60	Oral	167 ±29	13.2 ±2.5	1.39 ±.28	153 ±33	12.2 ±1.3	1.34 ±.27
60	I.V.	147 ±25	12.1 ±2.7	1.48 ±.30	134 ±28	10.3 ±2.3	1.19 ±.24
120	Oral	156 ±38	12.6 ±.3	1.24 ±.24	135 ±40	11.4 ±1.2	1.21 ±.22
120	I.V.	107 ±18	7.4 ±2.3	1.05 ±.22	105 ±16	9.1 ±3.4	1.04 ±.23
180	Oral	128 ±29	11.0 ±2.2	1.06 ±.23	112 ±30	9.2 ±1.4	.95 ±.14

Glucose Tolerance plus Exercise.—During March 1944, nine months after feeding of the deficient diet containing approximately 400 mcg. of thiamine was started, it was decided to apply the exercise at the time when the blood glucose was at a high level, in the hope that the double load of glucose and exercise would produce a more critical test of carbohydrate metabolism during thiamine deficiency. In order to determine what the time interval should be between the end of exercise and the blood withdrawal, an experiment was planned in which blood samples were taken at intervals of 1, 2, 5, and 10 minutes after exercise. This exercise consisted of the subject walking up, down, and up again, a flight of 21 steps 19 cm. high and 28 cm.

wide. The rate of climb and descent was controlled so that the exercise was performed during a period of 60 seconds. It was begun 60 minutes after the ingestion of glucose and immediately following the withdrawal of the 60-minute blood sample. Since the elapsed time of the exercise was one minute, the first sample taken after exercise was the 62-minute sample, the second the 63-, the third the 66-, and the last the 71-minute sample after glucose ingestion. Each of these was analyzed for glucose, lactic acid, and pyruvic acid. Because the averages of the results obtained do not adequately represent the actual variations, the individual data for the lactic and pyruvic acid concentrations are given in Table 10.

Analysis of the data in Table 10 shows some interesting differences between young and old subjects and between the rate at which the lactic and pyruvic acid levels in the blood reach maximum concentrations after exercise. That the older individuals give higher levels for lactic and pyruvic acid is perhaps not surprising, since they have higher levels of glucose in the blood after carbohydrate ingestion, a point which will be discussed in detail later. Of some interest is the fact that the peak of the lactic acid levels is attained sooner than that for the pyruvic acid. This is true for both young and old subjects.

It is known that pyruvic acid is the most reactive substance among intermediary products of carbohydrate metabolism. Consequently the more reactive pyruvate is present at any given time in much lower concentrations than lactate. The figures which show that the levels of pyruvic acid were still going up after the lactic acid had reached its peak levels provide data for conjecture regarding the possible equilibrium states of these two compounds.

As a result of the above series on the glucose-plus-exercise test and other experiments using exercise alone, a decision was made to choose the five-minute sample after exercise as the one upon which the workers should concentrate their attention.[1]

The relative value of the glucose-plus-exercise load test and the same test without the oral ingestion of glucose remained for some time a question which was not satis-

---

[1] Several years of accumulated experience with this test have left an impression that the sample taken 10 minutes after exercise may be better, even though somewhat more difficult to plan when a large group of subjects are being tested. Where no glucose is administered, a peak in lactic and pyruvic acid levels is reached about 5 minutes sooner than in the presence of extra glucose. It appears however, that the closer the physiological condition of an individual approaches a pathological state, the more likely he is to have a delay in reaching the maximum levels of pyruvic acid; and, since it is these pathological states that we are looking for, the 10-minute sample may be preferred to the sample taken 5 minutes after exercise. Considerable data having been accumulated on the 5 minute sample, it was necessary to continue the study with this procedure. However, were the authors to do this work again on old individuals the 10-minute sample would be used more extensively. This does not mean that the results with the 5-minute sample to be reported are not almost as valuable, since in practically every case where the 10-minute sample gave abnormally high results the 5-minute sample gave results which were higher than normal. And in many cases, especially with the younger individuals, the concentration peaks were obtained at 5 minutes after exercise (See Table 10).

It should be mentioned that experience with samples taken 15 minutes after exercise indicated that the values obtained at this time were always lower than those obtained during the 10-minute interval. Some examples of this will be shown later.

TABLE 10

CHANGES IN LACTIC AND PYRUVIC ACIDS AFTER GLUCOSE AND EXERCISE

SUBJECT	LACTIC ACID (MG%)						PYRUVIC ACID (MG%)					
	Time						Time					
	0	60	62	63	66	71	0	60	62	63	66	71
AO1	10.8	27.0	38.2	—	42.6	43.0	1.42	2.12	2.12	—	2.58	2.66
AO2	6.9	12.3	12.3	18.3	18.3	19.2	.80	.90	.90	.96	1.12	1.19
AO3	11.7	16.5	17.7	25.0	31.8	30.6	1.18	1.48	1.40	1.72	1.80	2.06
AO4	—	22.5	27.0	31.2	38.4	43.5	—	1.88	1.80	1.72	2.36	3.00
AO5	18.3	19.5	24.0	—	33.4	38.2	1.77	1.94	1.68	—	1.85	2.11
AO6	8.1	21.6	23.1	30.6	33.3	32.5	1.02	2.44	2.14	2.23	2.25	2.44
AO7	12.2	19.7	25.0	30.6	36.5	38.4	1.04	1.07	1.35	1.36	1.70	1.95
BO1	11.1	18.3	17.1	21.7	28.2	25.8	.92	1.08	—	1.38	1.72	1.73
BO2	10.5	13.8	19.0	24.9	24.5	25.8	1.00	1.18	1.42	1.40	1.52	1.78
BO3	10.5	17.3	20.6	30.4	33.4	31.2	1.12	1.36	1.47	1.56	2.06	2.28
BO4	7.5	14.0	16.4	26.1	29.1	30.4	.70	1.13	.96	1.29	1.72	2.06
BO5	11.4	23.7	23.2	29.2	27.6	30.0	1.24	1.86	1.66	1.94	1.84	2.30
BO6	13.2	20.3	21.6	20.3	24.0	25.9	1.18	1.40	1.38	1.40	1.41	1.98
BO7	11.3	12.6	21.0	34.0	33.0	32.4	1.00	.98	1.00	1.72	1.84	1.72
CO1	7.8	11.1	—	14.4	16.5	17.7	1.67	.78	—	.92	1.02	1.13
CO2	7.5	13.3	13.6	—	27.4	27.0	.60	1.18	.90	—	1.58	1.80
CO4	7.4	10.2	18.3	—	20.2	18.6	.48	.78	.82	—	1.32	1.40
CO5	11.4	16.0	30.4	—	33.2	30.4	1.16	1.00	1.16	—	1.17	1.80
CO6	11.6	17.6	—	29.8	38.4	38.4	1.42	1.84	—	2.18	1.64	1.97
Average Old.....	10.5	17.2	21.6	26.1	30.0	30.5	1.09	1.38	1.38	1.55	1.71	1.96
AY1	—	20.8	25.8	27.0	31.9	24.9	—	2.08	2.00	2.00	2.22	1.80
AY2	5.6	12.2	12.8	21.7	17.2	18.7	.74	1.28	1.24	2.15	1.56	1.88
AY3	11.7	23.7	24.0	31.2	30.6	31.6	1.09	1.58	1.07	1.58	1.58	1.98
AY4	7.4	14.3	14.7	21.2	22.0	19.2	1.01	1.68	1.31	1.68	1.80	1.68
AY5	12.0	17.7	21.5	33.6	28.1	21.9	1.13	1.32	1.49	1.80	1.79	1.46
BY1	—	7.3	11.3	17.1	14.4	14.5	—	1.24	1.28	1.32	1.38	1.73
BY2	8.7	11.7	13.8	16.9	15.7	16.9	.89	1.03	.94	1.03	1.30	1.65
BY3	6.8	8.1	11.5	11.0	11.1	11.0	.82	.97	1.16	1.02	1.09	1.24
BY4	—	14.4	—	—	—	13.9	—	1.00	—	—	—	.76
BY5	9.8	12.1	20.1	19.4	17.7	17.7	1.02	.91	1.34	1.72	1.18	1.93
CY1	9.5	19.5	19.0	—	19.7	18.0	1.08	1.48	1.22	—	1.62	1.62
CY3	9.9	18.9	21.0	—	27.9	22.5	.96	1.32	1.37	—	1.80	1.36
CY4	10.4	11.9	—	13.4	16.0	15.5	1.02	.89	—	.89	1.12	.96
CY6	9.9	14.3	21.6	20.2	26.7	25.8	.96	1.24	1.45	1.51	1.78	2.04
Average Young..	9.2	14.7	18.1	21.1	21.5	19.4	.97	1.28	1.32	1.51	1.55	1.58

factorily solved. To make possible a closer examination of the two technics, three subjects were chosen from each of the supplemented (B) groups after about 16 months of supplementation with yeast extract. Samples of blood were taken from these subjects just after arising in the morning and after 60, 66, 71, 76, 90, and 120 minutes, the standard one-minute stair-climbing test being applied at 60 minutes. A few days later the glucose-plus-exercise test, using the same time interval, was conducted on these individuals. Figures 2 and 4 give the glucose and lactic and pyruvic acid curves prepared by joining the points representing the averages of the data obtained at the stated intervals for both the glucose-plus-exercise test and the similar test without the ingestion of glucose. From these curves it is obvious that the individual obtaining adequate alimentation showed relatively little rise in lactic and pyruvic acid unless the blood levels of glucose were raised. In order to compare these results with those obtained on subjects who had been for 16 months on a diet containing less than 400 mcg. of thiamine, three patients from each of the depletion groups, who had had early signs of chemopathological changes, were tested without glucose as described above for the B group. The data obtained are compared with data obtained a few weeks before from a glucose-plus-exercise test. Figures 1 and 3 chart the averages of data for the AO and AY groups, respectively. A comparison of the results with those obtained from the supplemented group (Fig. 2 and 4) shows a very pronounced difference between the two dietary groups both for the glucose-plus-exercise and for the exercise alone. The differences obtained with exercise alone

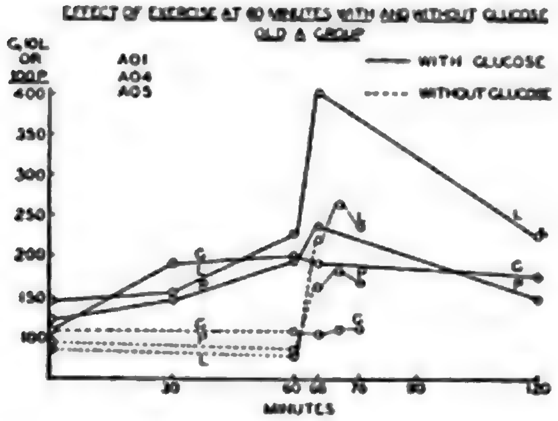


Fig. 1

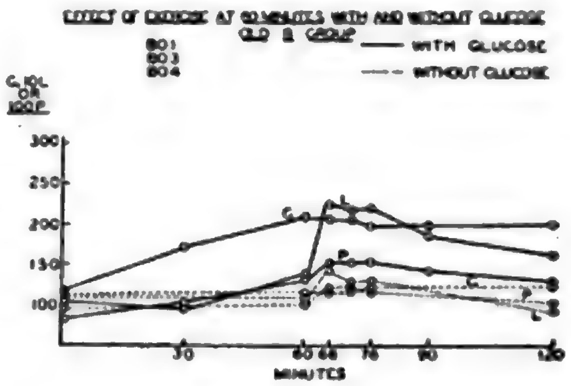


Fig. 2

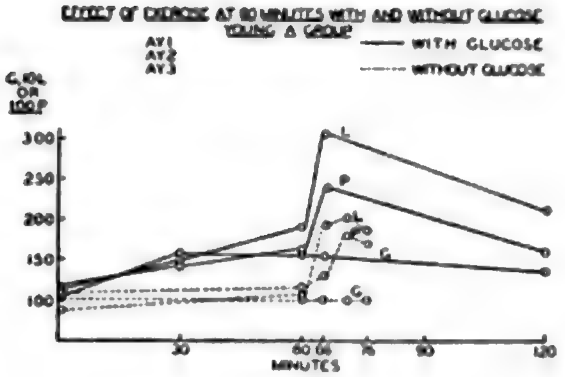


Fig. 3

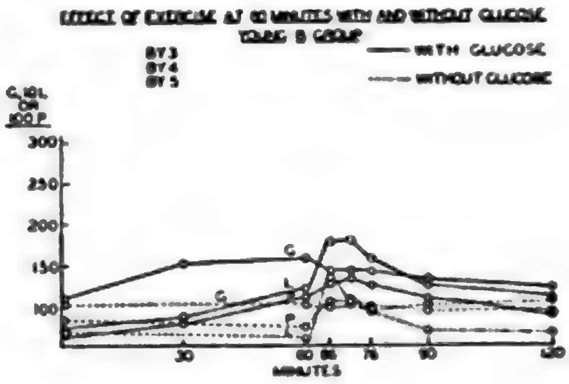


Fig. 4

Figs. 1–4. Comparison of the effect of exercise on blood levels of glucose (G), lactic acid (L), and pyruvic acid (P). All values in mgs. per cent.

are considerably smaller than those obtained if the exercise is applied when the blood sugar levels are elevated.

The foregoing paragraphs may establish a background for the discussion of the lactic and pyruvic acid data which follows.

RESULTS

The publication of the many data obtained during the course of the three year study of the variations in lactic acid and pyruvic acid presents a problem. Whether or not it is better to give averages for groups of subjects or to give the individual results in their entirety is debatable. It seems no more proper to average the results of a patient who shows no biochemical signs of thiamine deficiency with a member of the same dietary group who gives very high figures for lactic and pyruvic acids than it would be to attempt to average an individual who has signs of corneal vascularization with one that does not have any such signs. For unknown reasons not all individuals are equally susceptible to nutritional deficiency. It is perhaps better to present their individual levels of lactic and pyruvic acids, which will vary widely, than to average those having the high results with those having results that may be very low and obtain a non-decisive figure.

However, custom and efficiency demand that a summary be made in the presentation of the data. A choice has therefore been made as a result of which some of the lactic and pyruvic acid results, basal, 60, and 66 minutes (i.e. five minutes after exercise) are graphed for each one of the subjects in order to indicate the individual results (Figs. 5–27). To further show how the data varied by dietary groups, the average of the blood lactic and pyruvic acid levels have been plotted for the 60- and 66-minute samples (Figs. 28–31). The above-mentioned charts do not include some of the data on blood levels obtained at time intervals other than 0, 60, and 66 minutes.

An index of carbohydrate metabolism, to be discussed later, was developed for interrelating the glucose, lactic acid, and pyruvic acid blood levels. The group averages of the carbohydrate metabolism indices are depicted in Figure 32 and individual indices in Figures 33–36.

The need for knowing the level of glucose when evaluating the levels of lactic and pyruvic acid can be demonstrated by comparing the data obtained in September 1944 from subjects AY5 and BO3 (see Table 11). According to the lactic and pyruvic acid data in Table 11 it would seem that the subject BO3, who was in the supplemented group at that time, was showing signs of deficiency, since the levels of lactic and pyruvic acid obtained for this subject were considerably higher than those obtained for subject AY5.

As other data similar to these were accumulated, it became obvious that all factors which affected the glucose tolerance curve also affected the levels of lactic and pyruvic

---

FIGS. 5–27. Lactic and pyruvic acid curves and glucose level for individual subjects. Curves represent levels of lactic and pyruvic acid at 0, 60, and 66 minutes after administration of glucose. Vertical bars represent 60-minute glucose level. Vertical double lines indicate time when supplementation with yeast extract was started. Vertical single lines indicate time when supplemented diet of group B was changed to contain less than 200 mcg. of thiamine daily.

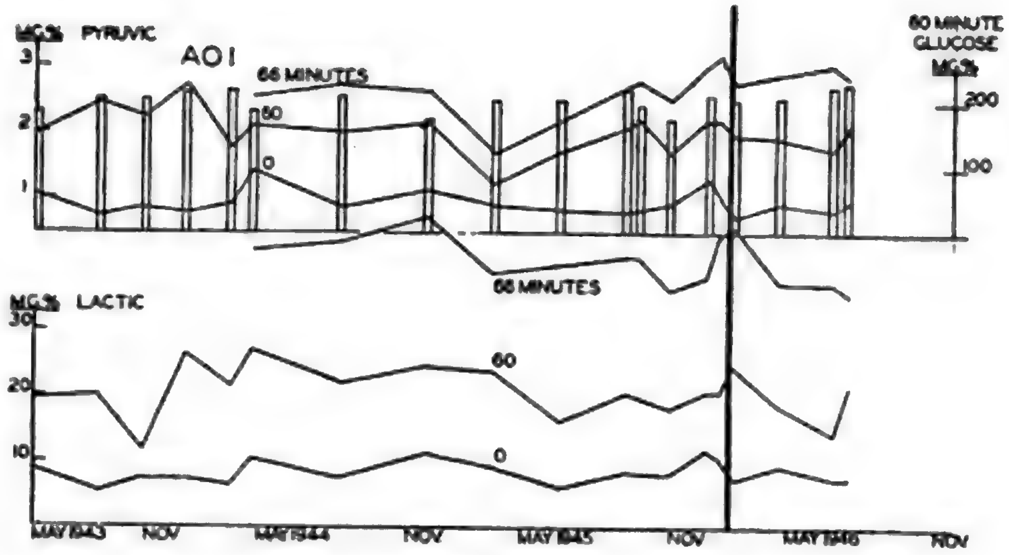


FIG. 5

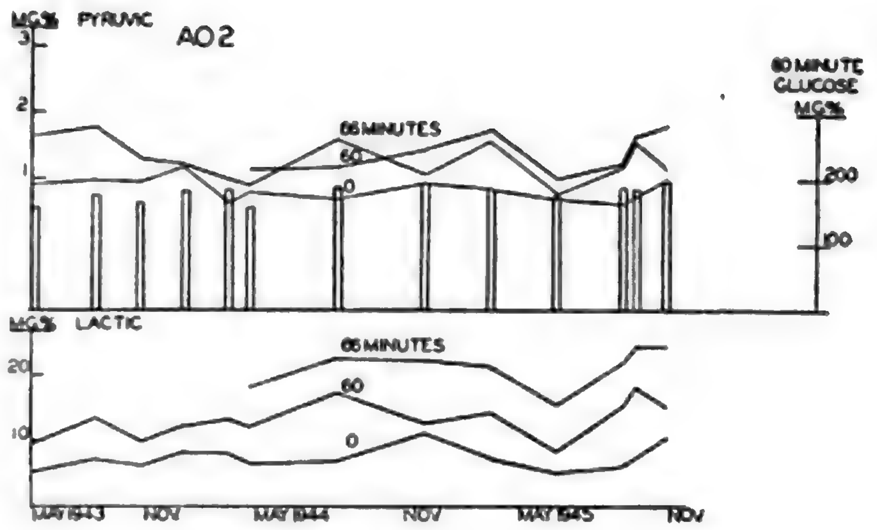


FIG. 6

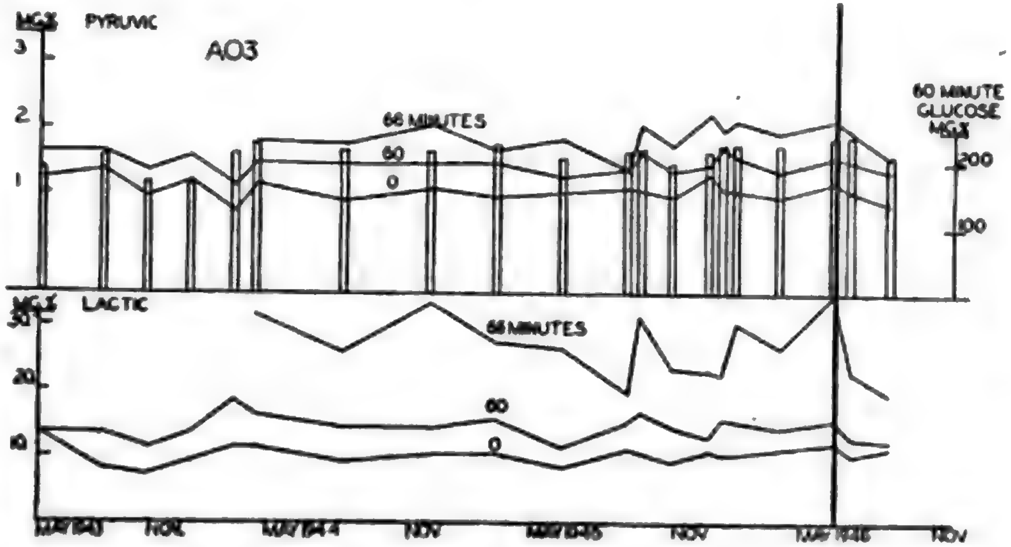


FIG. 7

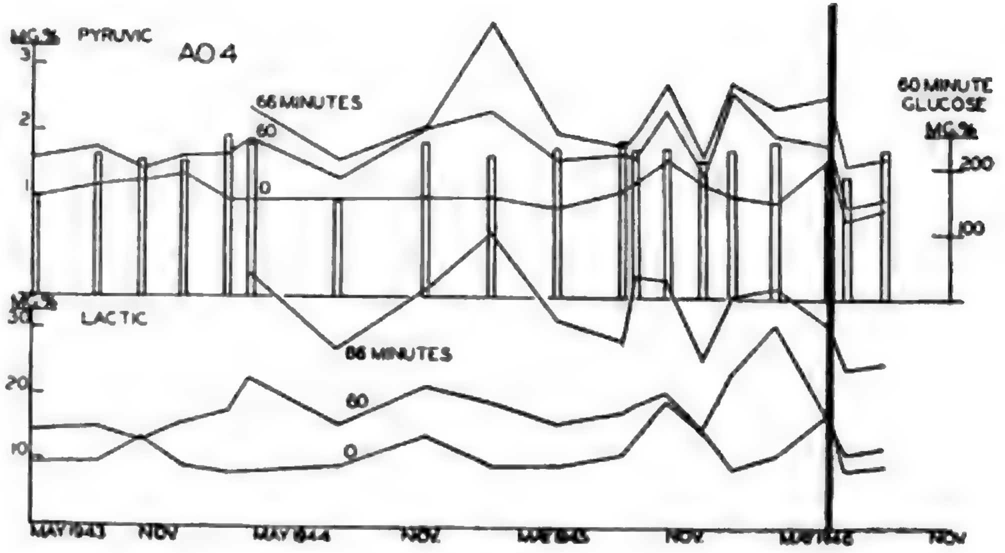


FIG. 8

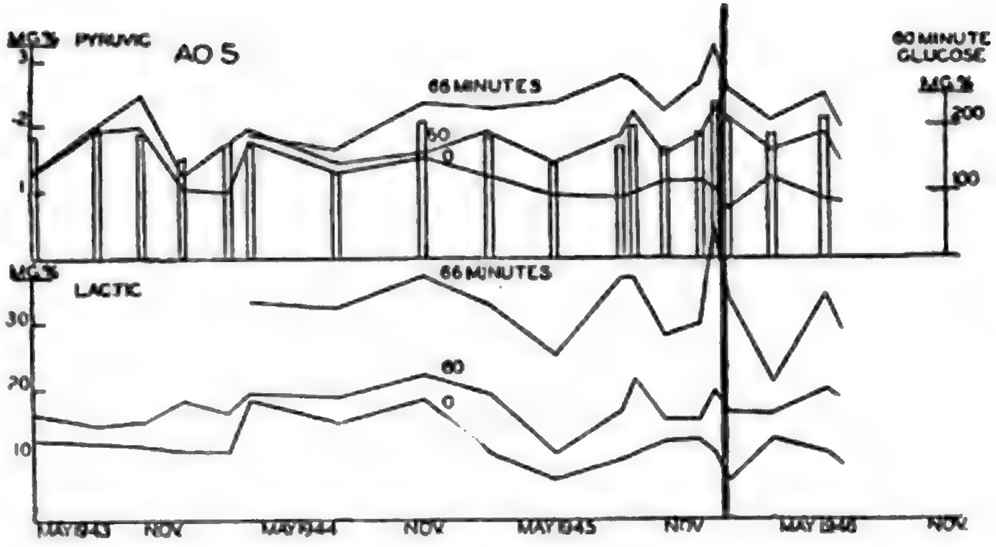


FIG. 9

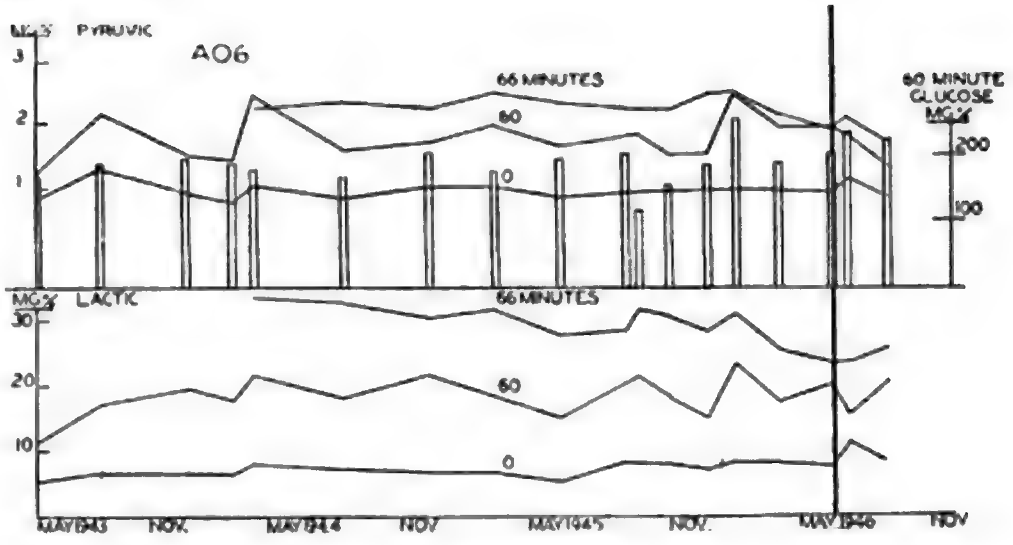


FIG. 10

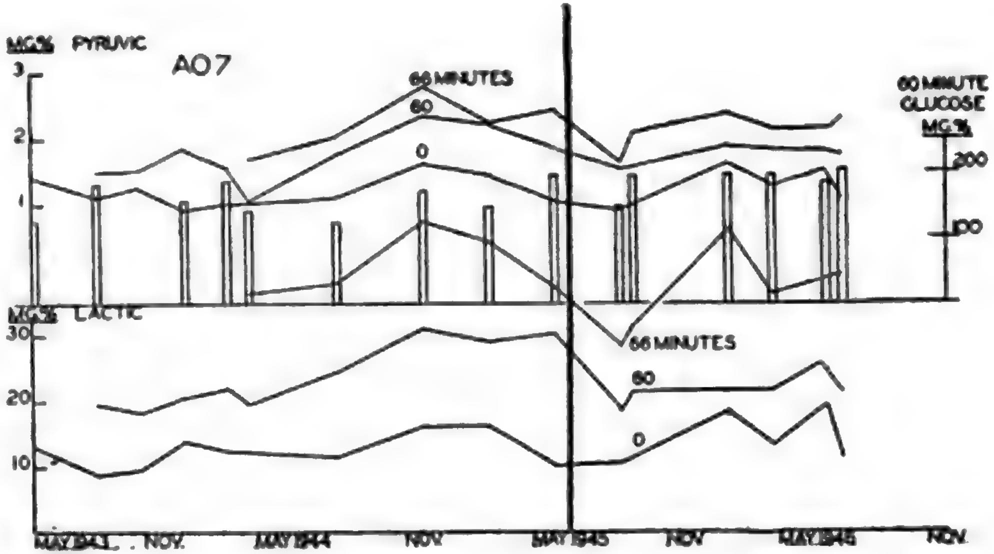


FIG. 11

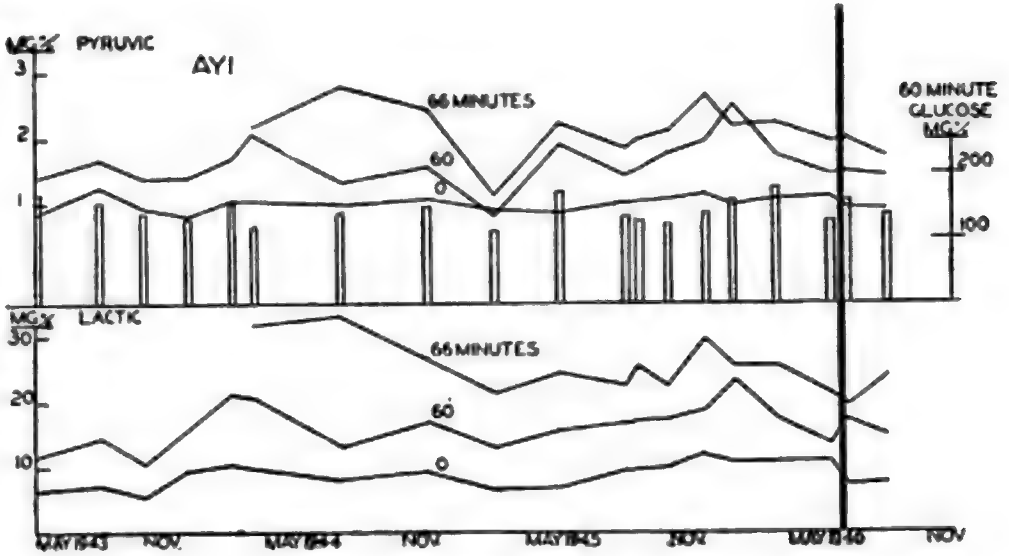


FIG. 12

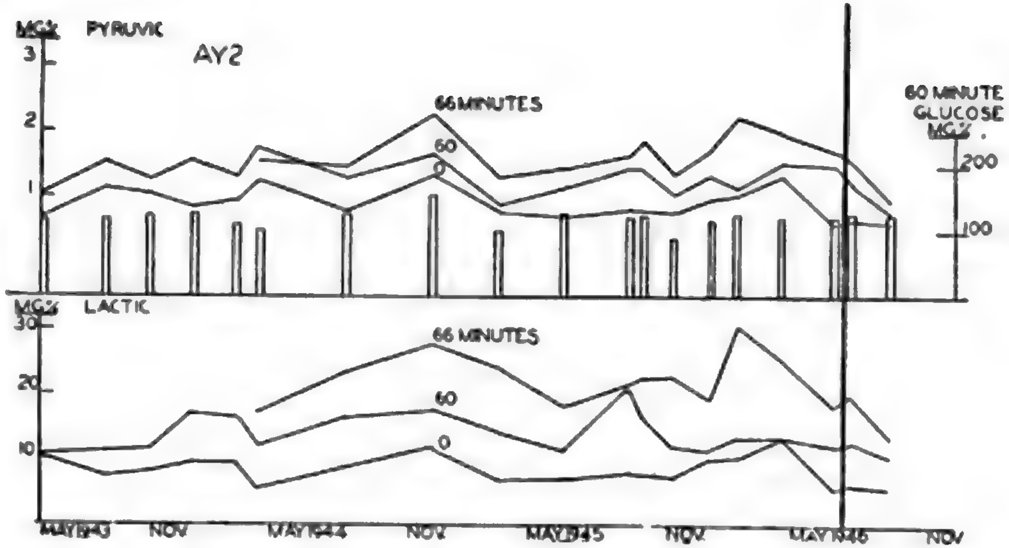


FIG. 13

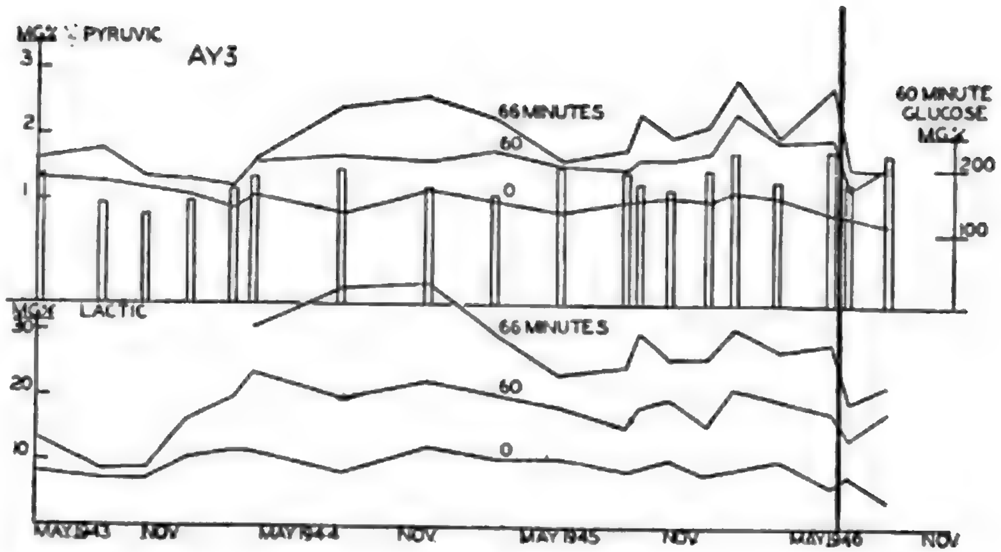


FIG. 14

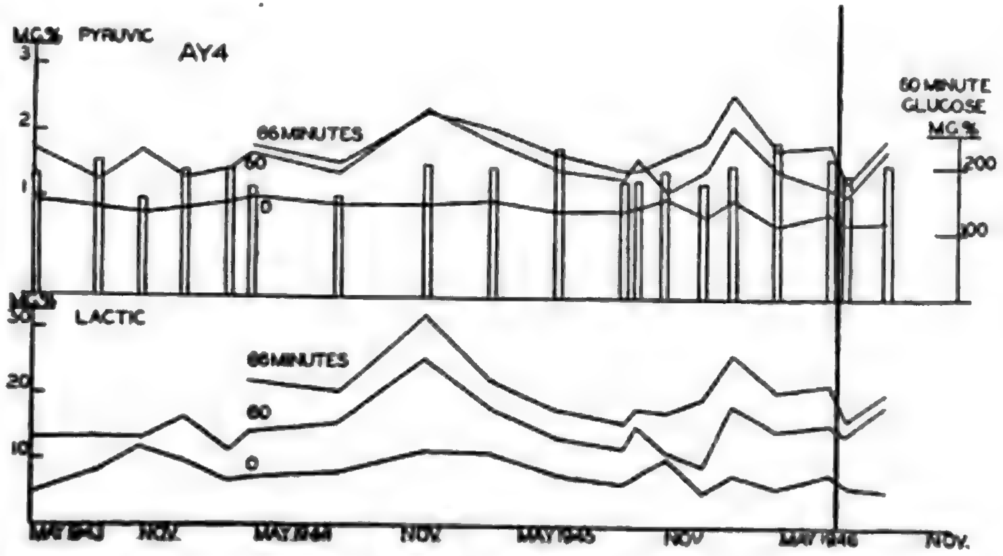


FIG. 15

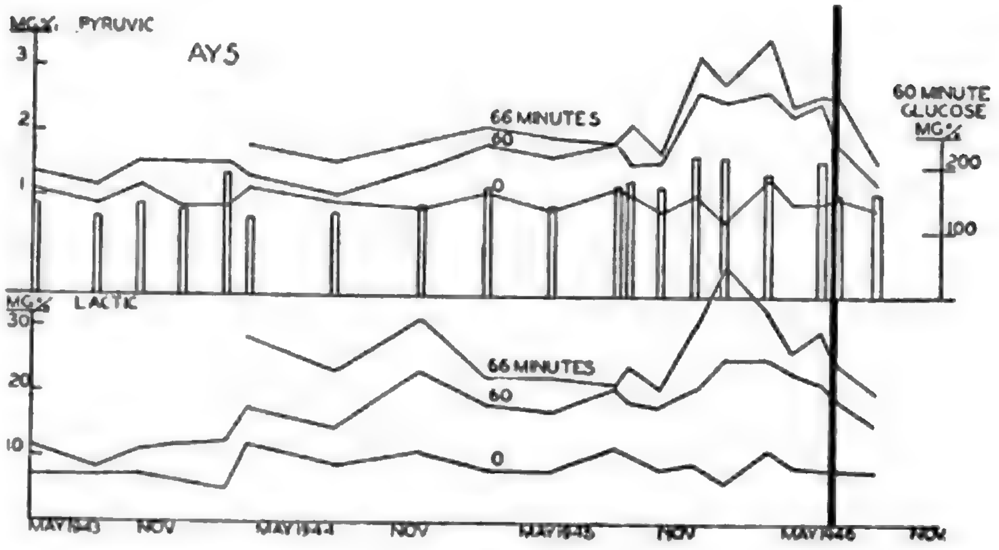


FIG. 16

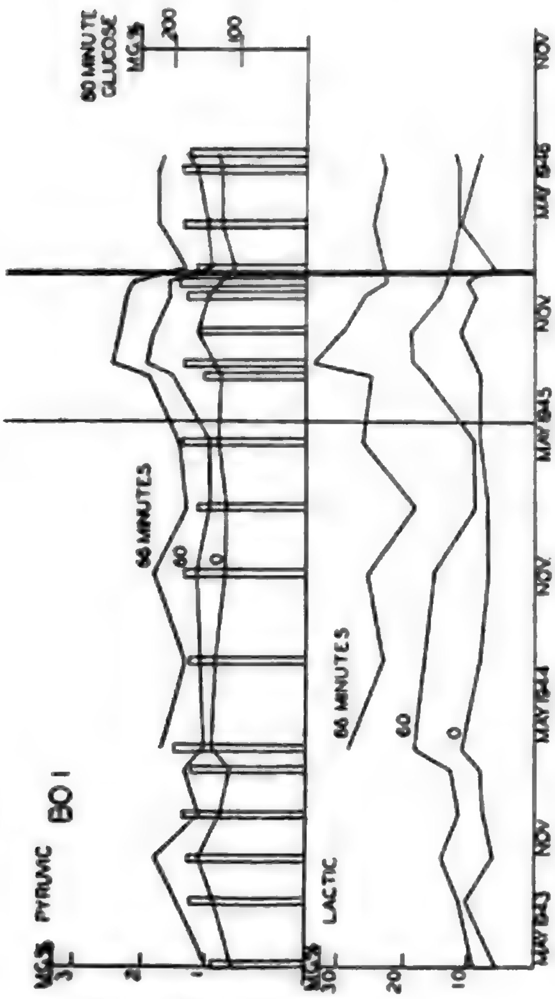


FIG. 17

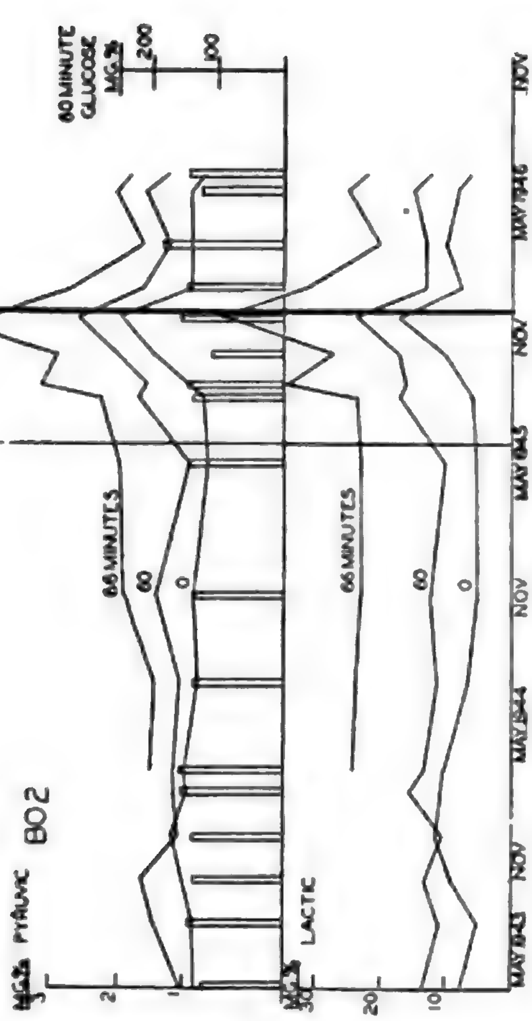


FIG. 18

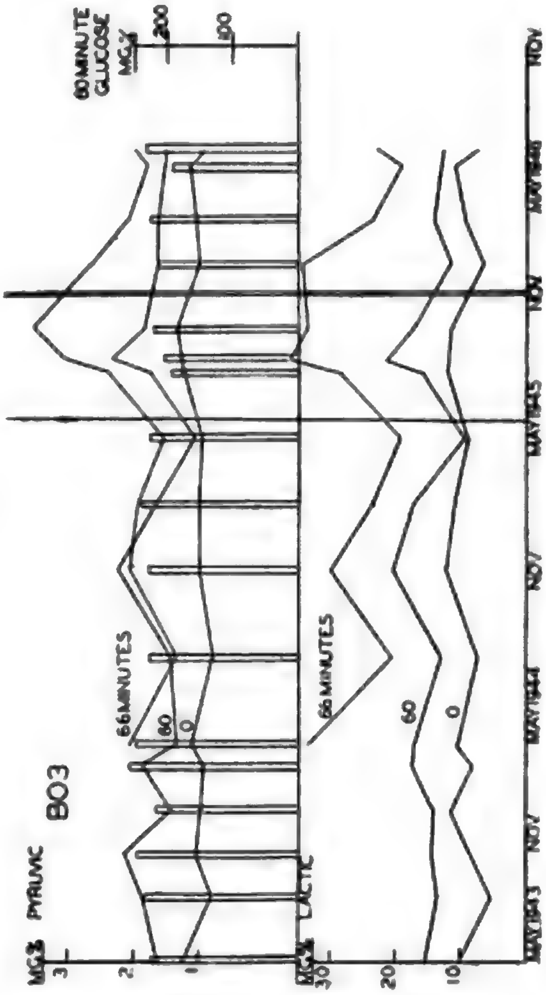


FIG. 19

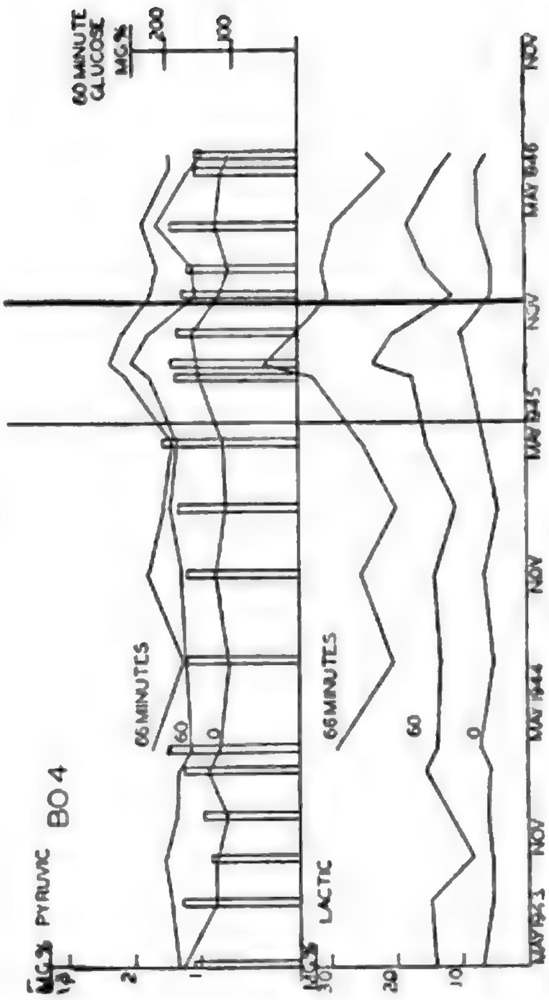


FIG. 20

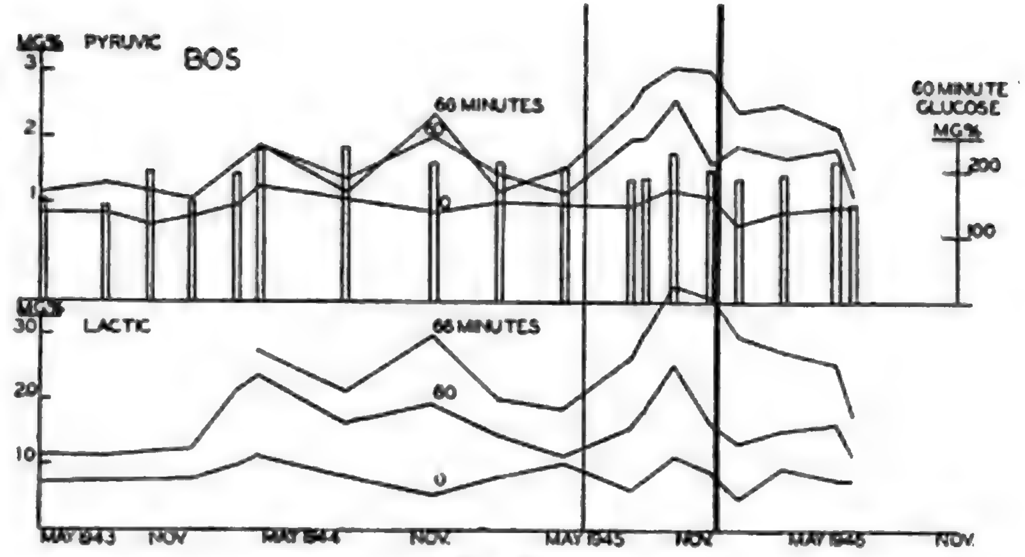


Fig. 21

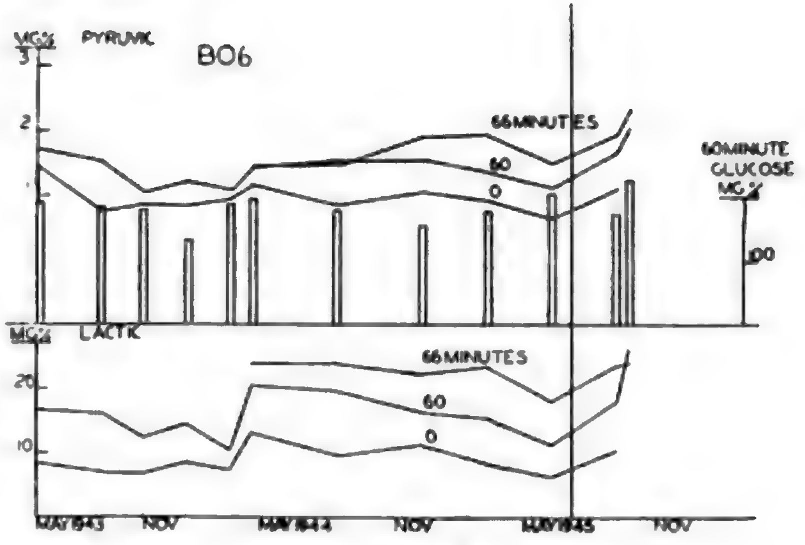


Fig. 22

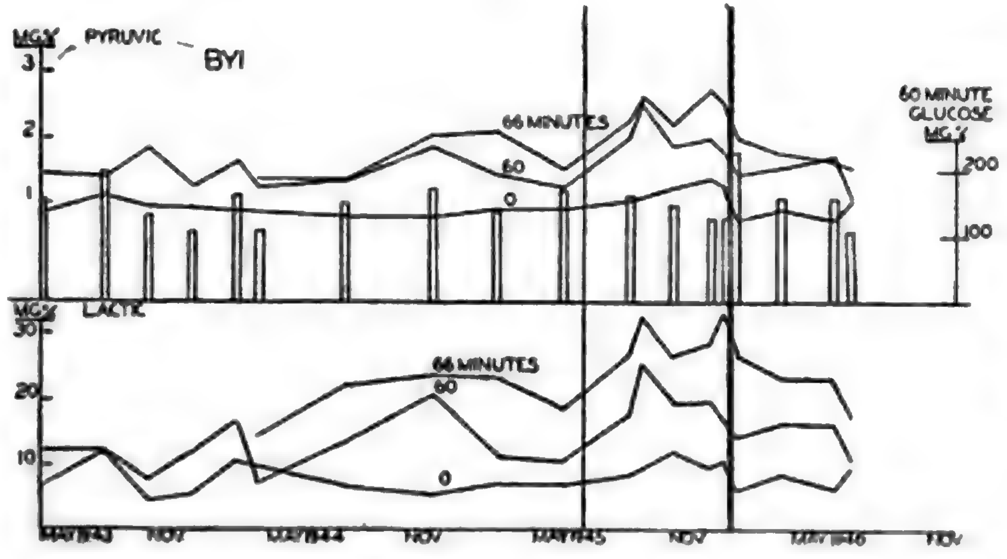


Fig. 23

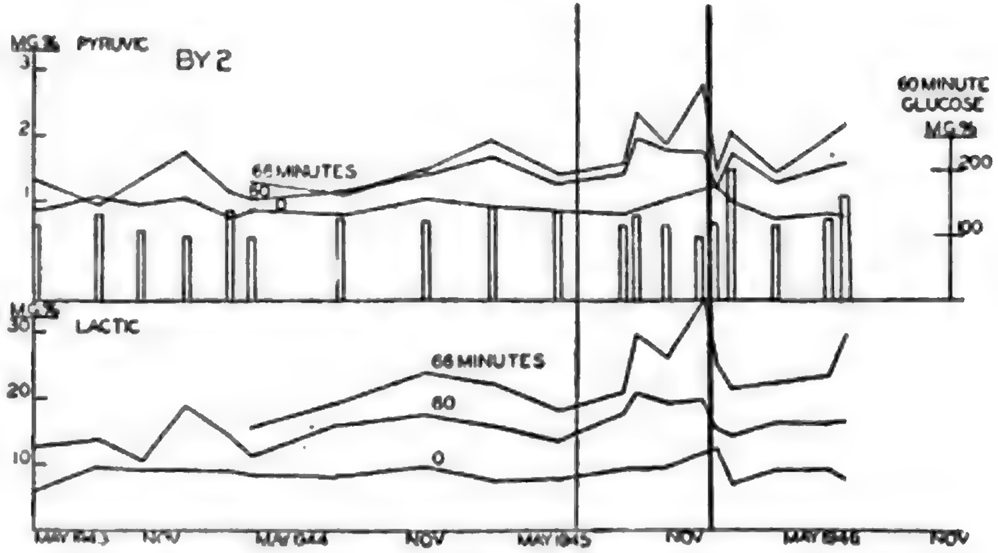


Fig. 24

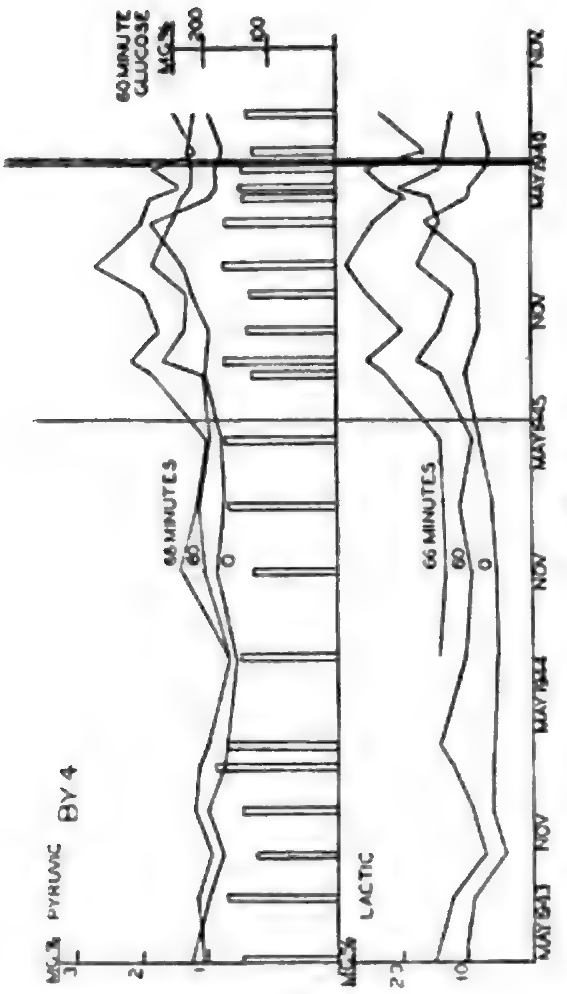


FIG. 26

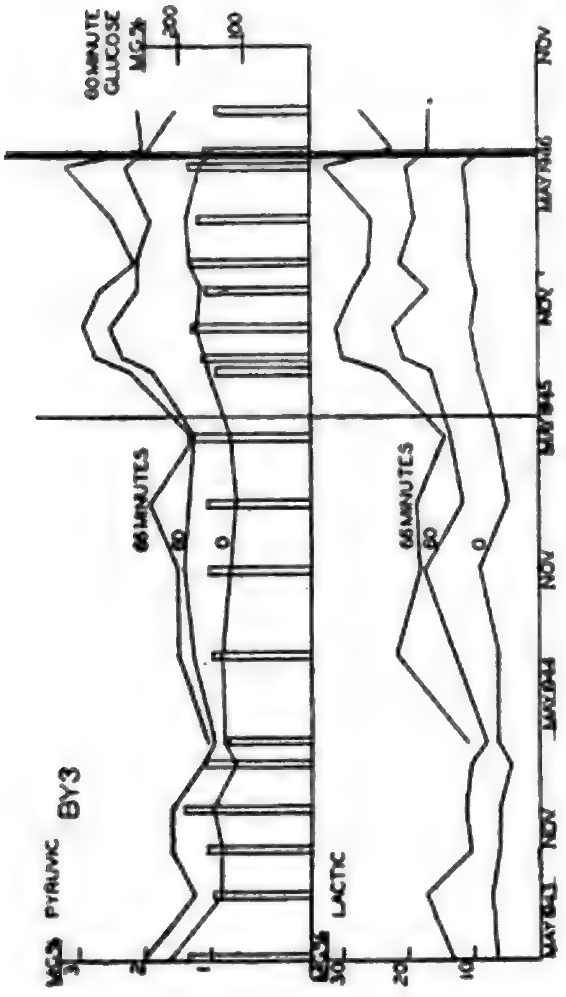


FIG. 25

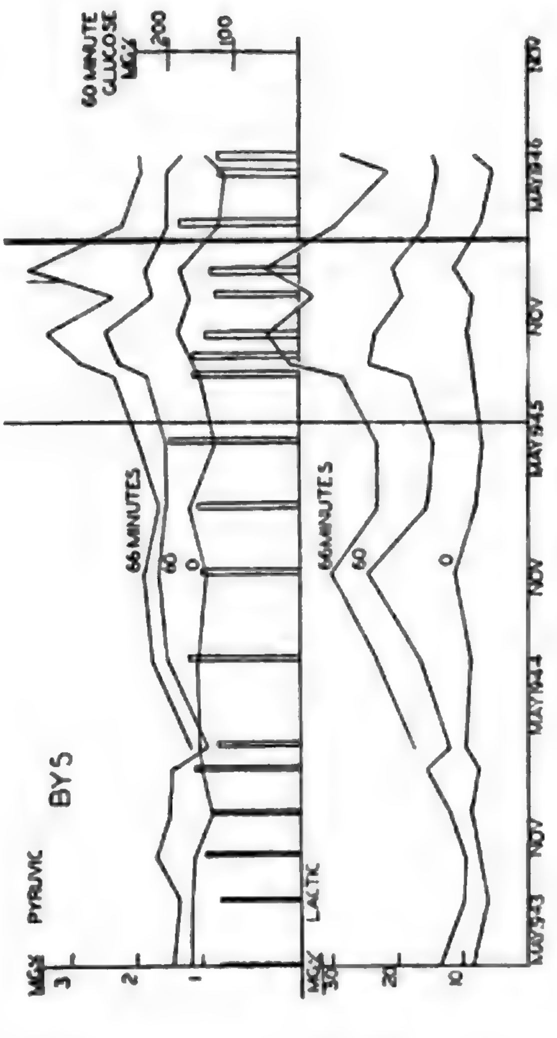


FIG. 27

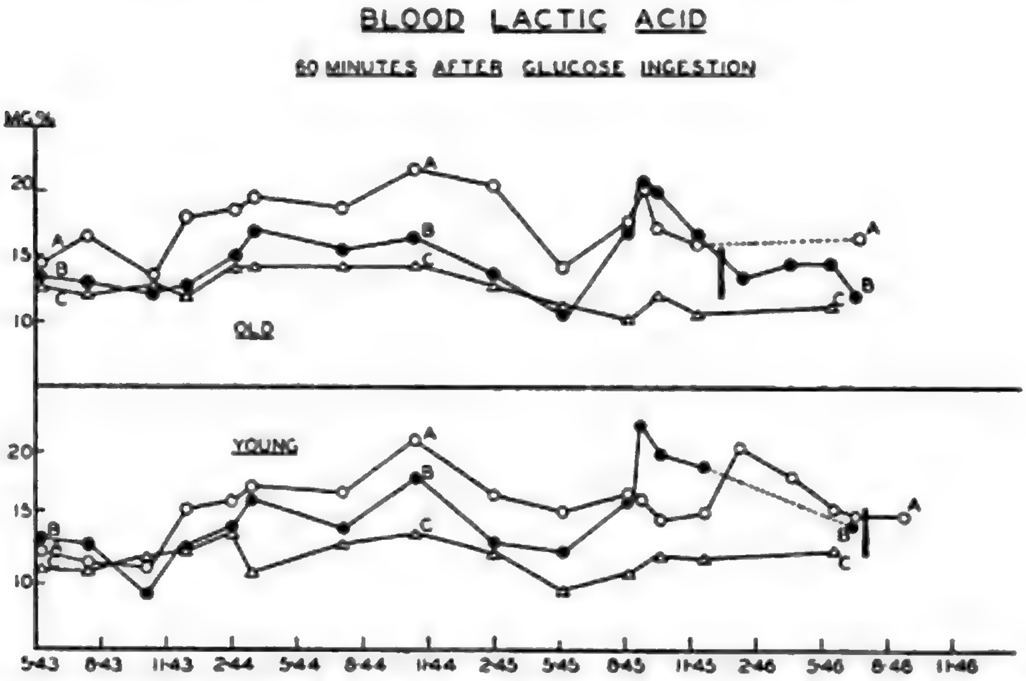


FIG. 28. Average lactic acid curves for the 60 minute blood sample. A designates test group, B designates control group, and C designates ad lib group. The vertical double line indicates the time at which supplementation with B-complex vitamins was started. The dotted lines connect points obtained before and after periods during which dietary regimens of the subjects of a given group were being changed not simultaneously. The diet of the B group was changed from one which was supplemented to one which contained 200 mcg. of thiamine per day on June 5, 1945.

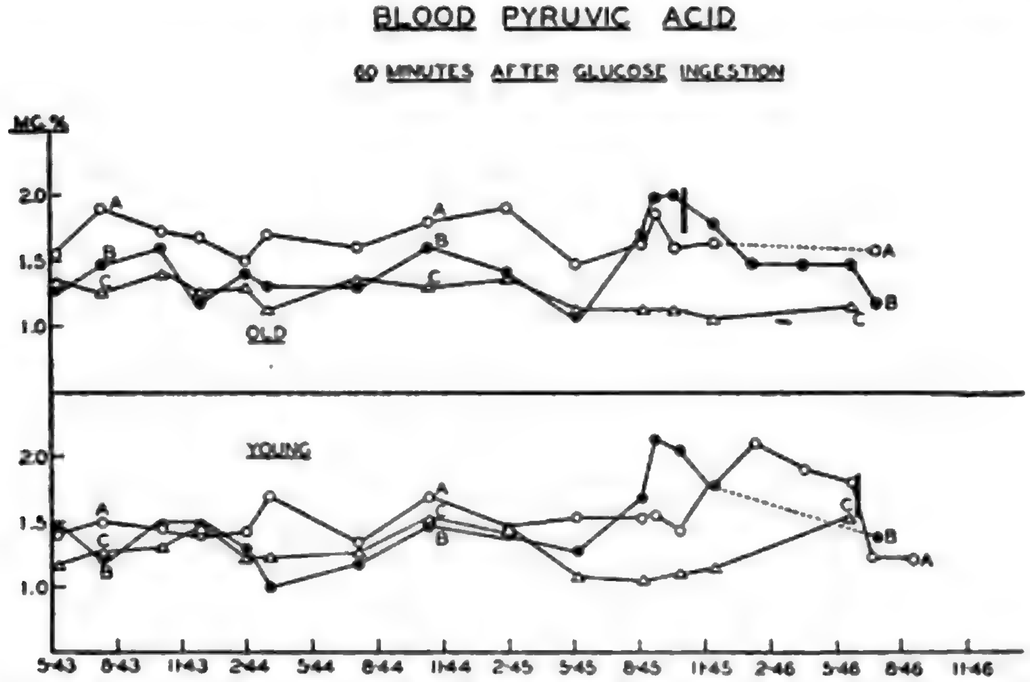


FIG. 29. Average pyruvic acid curves for the 60 minute blood sample. A designates test group, B designates control group, and C designates ad lib group. The vertical double line indicates the time at which supplementation with B-complex vitamins was started. The dotted lines connect points obtained before and after periods during which dietary regimens of the subjects of a given group were being changed not simultaneously. The diet of the B group was changed from one which was supplemented to one which contained 200 mcg. of thiamine per day on June 5, 1945.

acid to an extent that was proportional to the amount of glucose present in the blood stream at a given time. To compare two subjects at 60 minutes without considering

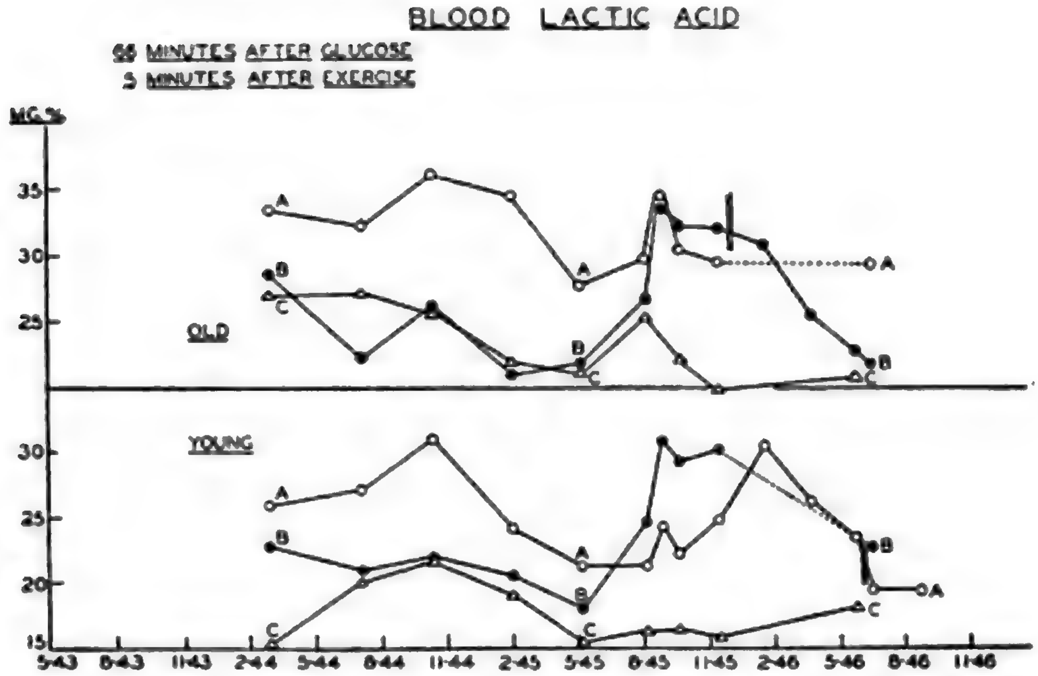


FIG. 30. Average lactic acid curves obtained after combined glucose load and exercise test. A designates test group, B designates control group, and C designates ad lib group. The vertical double lines indicate the times at which supplementation with B-complex vitamins was started. The dotted lines connect points obtained before and after periods during which dietary regimens of the subjects of a given group were being changed not simultaneously. The diet of the B group was changed from one which was supplemented to one which contained 200 mcg. of thiamine per day on June 5, 1945.

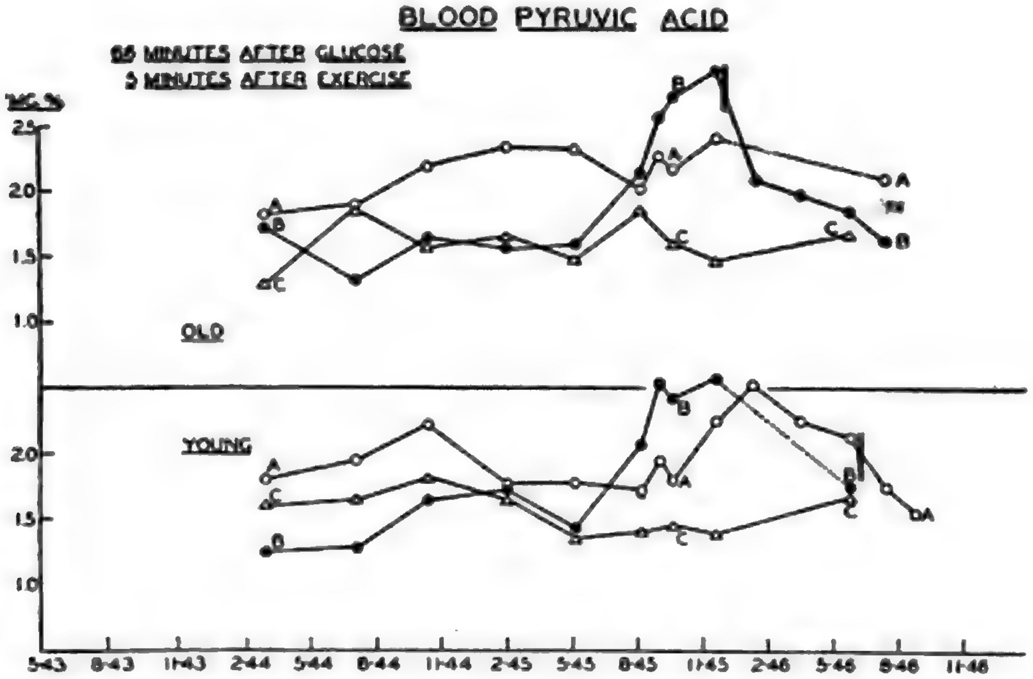


FIG. 31. Average pyruvic acid curves obtained after combined glucose load and exercise test. A designates test group, B designates control group and C designates ad lib group. The vertical double line indicates the time at which supplementation with B-complex vitamins was started. The dotted lines connect points obtained before and after periods during which dietary regimens of the subjects of a given group were being changed not simultaneously. The diet of the B group was changed from one which was supplemented to one which contained 200 mcg. of thiamine per day on June 5, 1945.

their glucose blood levels would be grossly incorrect. It is, therefore, necessary either to compare the experimental subjects at similar levels of glucose concentration in the blood or to make some correction for the glucose level at the time at which the blood for the pertinent lactic and pyruvic acid figures was obtained. Table 11 gives a rather extreme example of the differences observed. The fact that BO3 is somewhat arteriosclerotic and his 180-minute sample gave higher glucose levels than were obtained at 60 minutes emphasizes the need for knowledge and consideration of the glucose levels. An arithmetical aid to facilitate the comparison of the lactic and pyruvic acid levels obtained at a given time interval after glucose administration is discussed later in this section.

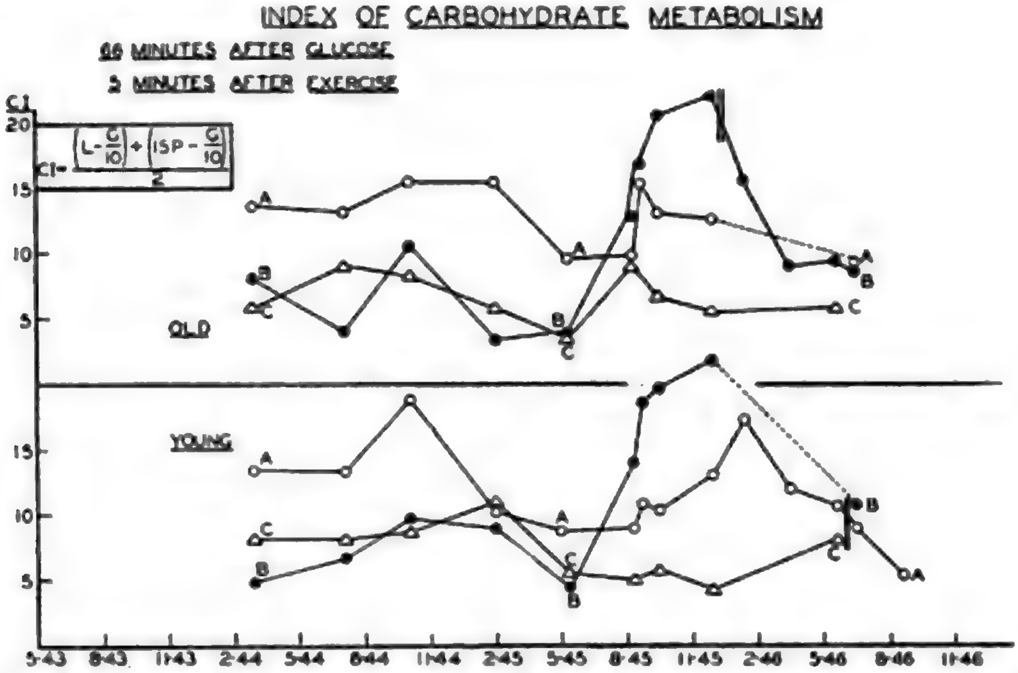


FIG. 32. Average Index of Carbohydrate Metabolism (CI) obtained by relating the glucose (G), lactic (L) and pyruvic acid (P) levels of the blood after the combined glucose-exercise test. A designates test group, B designates control group and C designates ad lib group. The vertical double lines indicate the times at which supplementation with B-complex vitamins was started. The dotted lines connect points obtained before and after periods during which dietary regimens of the subjects of a given group were being changed not simultaneously. The diet of the B group was changed from one which was supplemented to one which contained 200 mcg. of thiamine per day on June 5, 1945.

Glucose, Lactic, and Pyruvic Data.—Figures 5 to 27 represent the lactic and pyruvic acid data at 0, 60, and 66 minutes after glucose ingestion for each subject. The upper half of each of these figures represents the changes occurring in the pyruvic acid levels at the time intervals indicated, and the lower half represents the lactic acid results obtained at the same time. The height of the vertical bars is proportional to the level of glucose in the blood 60 minutes after the ingestion of glucose on the day during which the metabolic load test was administered.

The vertical lines in Figures 5 to 27 serve to divide the different dietary periods. The basal diet containing 400 micrograms of thiamine and 800 micrograms of riboflavin was fed to all but one of the patients in the A group for more than two and one half years. The double vertical lines represent the time at which the yeast

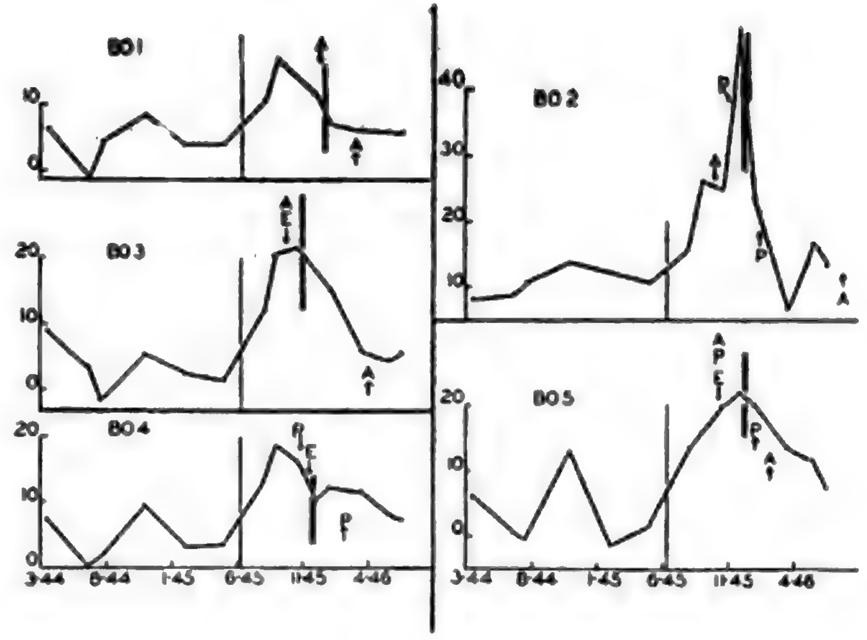


FIG. 33

FIG. 33. Individual Indices of Carbohydrate Metabolism for subjects in the old B group. The vertical line indicates the time at which yeast extract was withdrawn from these subjects and the thiamine content of the diet was dropped to 200 mcg. per day. The double vertical line indicates time at which yeast extract was added to the daily regimen. A, P, and E, with descending arrows indicate the time at which there was a definite decrease in response to stimulation of the Achilles and patellar reflex, and signs of edema, respectively. The ascending arrows indicate the time at which these clinical signs showed definite improvement.

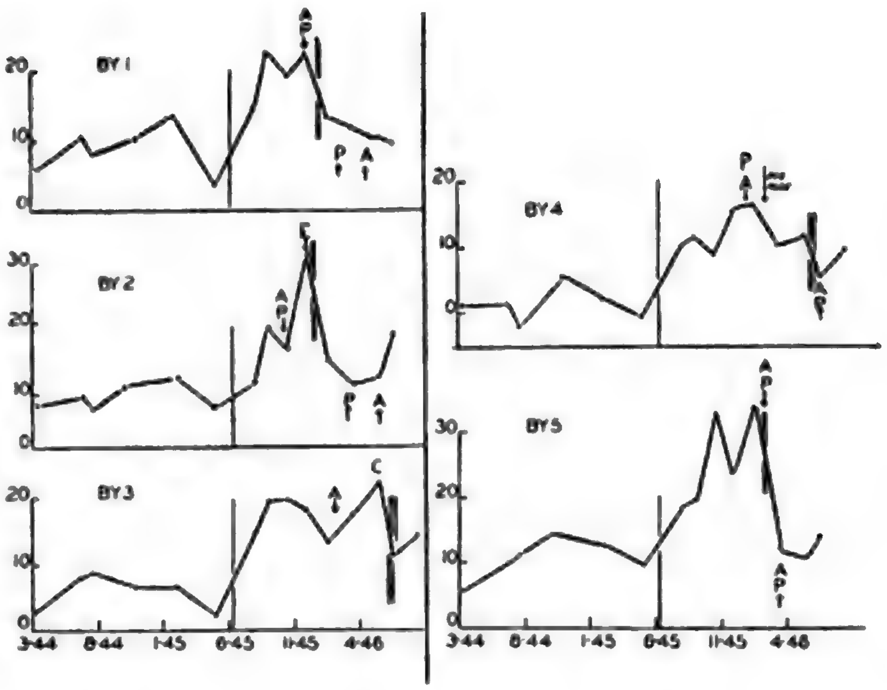


FIG. 34

FIG. 34. Individual Indices of Carbohydrate Metabolism for subjects in the young B group. The vertical line indicates the time at which yeast extract was withdrawn from these subjects and the thiamine content of the diet was dropped to 200 mcg. per day. The double vertical line indicates time at which yeast extract was added to the daily regimen. The triple vertical line indicates the time at which the synthetic vitamins were added instead of yeast extract. A, P, and E, with descending arrows indicate the time at which there was a definite decrease in response to stimulation of the Achilles and patellar reflex and signs of edema, respectively. The ascending arrows indicate the time at which these clinical signs showed definite improvement.

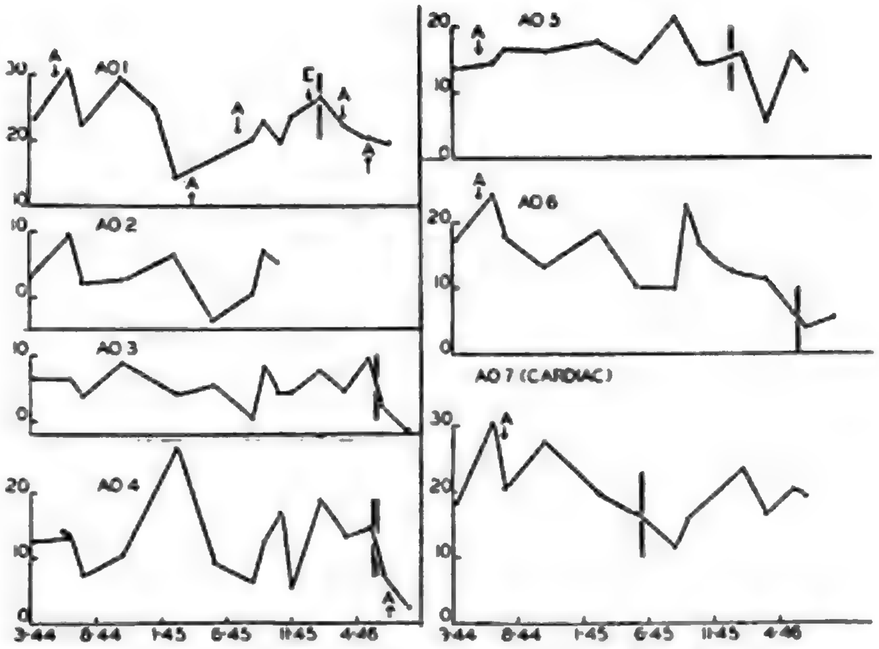


FIG. 35

FIG. 35. Individual Indices of Carbohydrate Metabolism for subjects in the old A group. The double vertical lines and the triple vertical lines indicate the times at which yeast extract or thiamine, respectively, were added to the daily regimen. It should be noted that this group which obtained a diet containing 400 mcg. of thiamine per day showed marked oscillations in CI, possibly due to alternate manifestations of deficiency and recovery on a diet which was borderline for most of the subjects of this group.

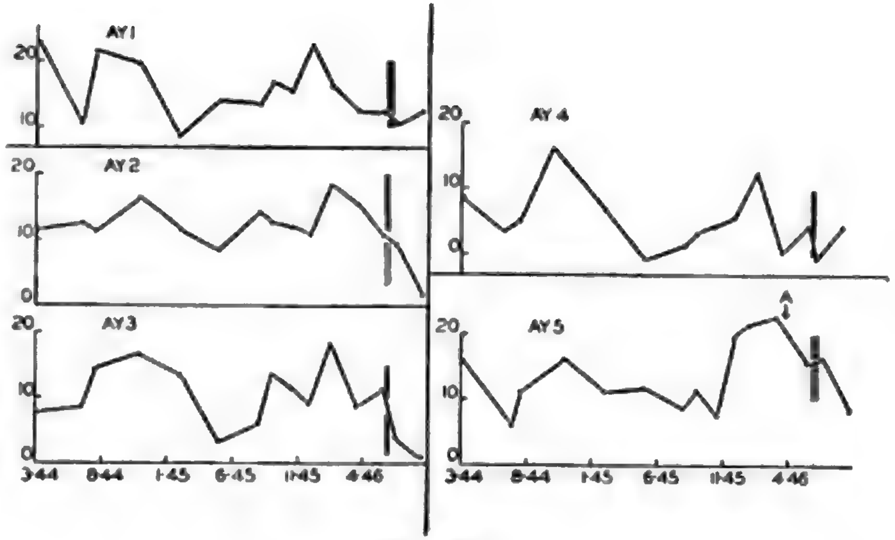


FIG. 36

FIG. 36. Individual Indices of Carbohydrate Metabolism for subjects in the young A group. The double vertical lines and the triple vertical lines indicate the time at which yeast extract or thiamine, respectively, were added to the daily regimen. It should be noted that this group which obtained a diet containing 400 mcg. of thiamine per day showed marked oscillations in CI, possibly due to alternate manifestations of deficiency and recovery on a diet which was borderline for most of the subjects of this group.

extract containing 6 mg. of thiamine and 1.2 mg. of riboflavin was added to the diet. In four cases the subjects were "reversed" with synthetic vitamins for a time before the yeast extract was added. The time of the addition of the synthetic vitamins is designated by a triple line.

The B group received the same basic diet as the A group, plus the yeast supplement for the period from June 1943 to June 1945. During the latter month, the diet of the B group was changed to one in which the thiamine content was reduced to approximately half that of the former basal diet (the riboflavin content remaining approximately the same) and the time of the change is designated by a single vertical line. The yeast extract was taken away from this group at the same time and they, therefore, became the more deficient subjects after having been on a supplemented regimen for two full years. As in the figures for the subjects in the A group, a double line represents the time at which yeast extract and the triple line the time at which a synthetic vitamin was added to the daily regimen. In all but one case, that of subject BY4 in which riboflavin in 6 mg. amounts was given daily, 6 mg. of thiamine was the supplement indicated by the triple line.

TABLE 11

COMPARISON OF LACTIC AND PYRUVIC ACID LEVELS OF TWO SUBJECTS WITH LOW AND HIGH BLOOD GLUCOSE LEVELS, RESPECTIVELY

SUBJECT		TIME IN MINUTES			
		0	60	120	180
AY5	Glucose (Mg %)	104	137	118	90
	Pyruvic (Mg %)	1.00	1.48	1.29	1.24
	Lactic (Mg %)	7.8	11.1	9.4	9.8
BO3	Glucose (Mg %)	98	244	260	165
	Pyruvic (Mg %)	1.20	2.43	1.86	1.38
	Lactic (Mg %)	8.5	14.5	14.2	12.2

The results of an attempt to combine some of the more important data and present them as averages of the various age and dietary groups are given in Figures 28 to 31. These figures include results obtained on the C group, which lived together with the subjects on the experimental diets but left the building for meals in one of the general dining rooms of the hospital. The figures compare the average levels of lactic acid and pyruvic acid for the three old and the three young groups obtained at different times during the course of the investigation. Figures 28 and 29 give the average levels of lactic acid and pyruvic acid, respectively, obtained 60 minutes after glucose ingestion. Since the subjects who were nutritionally deficient were supplemented at different times in accordance with clinical recommendations, it was not always possible to average the groups during the latter months of the experiment. Where the times of supplementations within a group varied greatly, dotted lines were used to connect points before and after such mixed periods. Figures 30 and 31 present similar data on lactic and pyruvic acid levels, respectively, obtained 66 minutes after glucose ingestion, that is, five minutes after the standard exercise test was completed. Since this exercise test was not used until March 1944, the averages represented by the curves on these two figures do not commence before this date.

An evaluation of the effect of the restricted diet upon the individual subject can now be made in terms of the facility with which the subject can handle the products of carbohydrate metabolism. Figures 5 to 11, which are for the AO group, are characterized by marked oscillations of the levels of lactic acid and pyruvic acid. These curves represent results obtained during the entire course of the study. The individuals involved were subsisting on a diet containing approximately 400 micrograms of thiamine and 800 micrograms of riboflavin for each 2200 calories consumed. It is possible that this borderline dietary regimen created a situation in these old men which was characterized by periods of mild deficiency followed by spontaneous recovery. These oscillations are especially marked in subjects AO1, AO4, and AO5. Each of these subjects showed some signs of improvement after the yeast extract was administered (see area to the right of the double vertical line). AO2 presented results throughout the study which were quite different from most of those obtained from other individuals in the group. The experiment with him was terminated in October 1945 when it was discovered that he had a carcinoma of the prostate. AO3 and AO6 showed relatively few changes with time. It is to be regretted that the exercise test was not developed until March 1944, nine months after the deficient diets had been started, since many of the subjects in the A group gave results with this test that were considerably higher than those obtained in the B group during March 1944.

The diet of subject AO7 was reversed by adding yeast extract in May 1945 because he showed signs of cardiac decompensation. There was considerable improvement in his condition for some time after yeast extract was started. But this might be attributed to the clinical management of his cardiac condition and may not be related to the increase of thiamine in his diet.

Except for one subject, AY5, who began to give very high results for lactic acid and pyruvic acid after two and one half years on the A diet, the young subjects AY1 to AY5, who received the same diet as the old subjects just discussed, gave lactic and pyruvic acid results which were consistently lower than those obtained for the older group. (See Figures 12 to 16.) This difference between the young and old subjects was probably due more to differences in levels of glucose during the test period than to any other factor, and a correction for the amount of glucose present in the blood tends to bring the two sets of data closer together. In general these curves were elevated to a point beyond that obtained for the B group (Figures 17 to 27) during the period when the latter group was receiving yeast extract. The oscillations shown by all these subjects in the data obtained from the exercise test point strongly to the possibility that they were in a condition of borderline deficiency and were going in and out of states of minimal abnormality.

The old B group (Figures 17 to 22) (BO1 to BO6) gave results which on the whole were considerably lower than those obtained with the old A group for the two-year period before June 1945, during which time they were being supplemented with the yeast extract. Within three months after their diet had been changed to one containing approximately 200 mcg. of thiamine, the lactic acid and pyruvic acid data on all these subjects began to show a marked increase. In most cases this increase was continued until a point was reached at which it was decided by the clinicians responsible for the welfare of the subjects that the period of vitamin deprivation should be terminated and yeast extract was added to the diet. In every case in this group the results of lactic acid and pyruvic acid tests were lower on the first test just after the yeast extract was given than they had been before the administration of yeast extract. The primary objective of creating in old men a nutritional deficiency which could be reversed was attained with the subjects in the B group. A correlation of the lactic acid and pyruvic acid data with the onset of some other clinical findings will be given later in this section.

The young B group (Figures 23 to 27) also gave results which were lower than the corresponding data obtained from their controls in the young A group, during the first two years of the experiment. Within two months after their diets were restricted to one containing only 200 micrograms of thiamine, these subjects (as well as the old B group subjects) began to show elevations of lactic and pyruvic acid at the 60- and 66-minute test periods. These elevated figures, which were especially marked after the combined glucose-ingestion-plus-exercise test, continued to show increases for the next few months, a period in which pronounced clinical signs of thiamine deficiency were observed. The *basal* levels of lactic and pyruvic acid did not rise until after the signs of clinical deficiency (which will be described in a later section) had appeared. They, therefore, are of little diagnostic use in evaluating minimal thiamine deficiency. The data involving the glucose-plus-exercise metabolic loads indicated that a test might be devised which would show the onset of thiamine deficiency approximately two months before any clinical changes in reflex action could be demonstrated.

The relative value of the 60- and 66-minute periods of observation in detecting signs of nutritional insufficiency is brought out by comparing data obtained when certain subjects were placed in bed as a precautionary measure during the period when neurological pathology was becoming apparent. In several cases in the B groups, *e.g.* BO3, BO5 and BY2, the test of the subject, after he had been kept in bed for an extended period as a precautionary measure following the appearance of signs of thiamine deficiency, gave data which indicated improvement at the 60-minute period, but the data for the test at 66 minutes, following exercise, did not bear this out. It would seem that the bed rest, which definitely decreases the need for thiamine, accounts for sufficient amelioration of the symptoms so that the subject can withstand the glucose load test in an improved manner. However, the physiological reserve that the subject may have accumulated as a result of the bed rest was not in these cases sufficient to withstand the additional load of having the exercise added to the glucose ingestion.

INDEX OF CARBOHYDRATE METABOLISM

The value of any group of data on lactic and pyruvic acid in human subjects will, to a large extent, depend upon a simplification of the interpretation of such data. It is apparent that the rise in the basal levels of lactic and pyruvic acid are not of much diagnostic value, since, even in those cases where there were pronounced elevations of the basal levels after the deficiency had progressed to a relatively severe state, the fluctuations during the early periods of depletion remained well within so-called normal levels. If a diagnosis is to be made before signs of nutritional deficiency are very obvious it is necessary to make use of one of the metabolic load tests, since it provides a better estimation of the chemopathological changes which have taken place.

It already has been shown that the glucose itself caused marked differences between different individuals in the levels of lactic and pyruvic acid obtained. Therefore the absolute value of the lactic and pyruvic acid after glucose administration is not dependable as an indication of early metabolic pathology unless cognizance is taken of the relative amounts of glucose in the blood at the times when the tests are being made. Comparison of a group of individuals who all have similar glucose tolerance curves could be made without such a correction. However, such a situation was not present among the subjects described in this report.

An extreme example of increase in the basal levels of lactic and pyruvic acid was observed in a group of diabetic patients at a time when they were not receiving insulin. There was positive correlation between the levels of lactic and pyruvic acid and the level of blood glucose. Administering glucose alone had relatively little effect upon the elevated levels of lactic and pyruvic acid. However, the addition of mild exercise to these diabetic patients caused a rise in the lactic and pyruvic acid levels which might be interpreted as representing severe thiamine deficiency unless the large amount of glucose present was taken into consideration.

It should be emphasized that the exercise test described in this report differs from certain other exercise tests used in the evaluation of thiamine deficiency in one important respect. The attempt was made to keep the amount of exercise at a minimum in order to test tissue metabolism rather than cardio-vascular efficiency. While it is understood that it is not possible completely to differentiate between the accumulation of metabolic end-products and the ability of the cardio-vascular system to remove these products, one should, nevertheless, not permit so much exertion that the accumulation of lactic and pyruvic acid becomes greater than the normal ability of the blood to remove them from the site of formation. Under conditions where the rate of production of these products (i.e. metabolism) exceeds the maximum ability of the transportation system to remove them and supply material for repair (i.e. blood circulation), the assay of a blood sample would give a result which could be more a function of cardio-vascular efficiency than of carbohydrate metabolism. This simplified explanation of the process is not intended to belittle the importance of other organs involved in carbohydrate metabolism, but may serve to help explain the reason for the insistence upon minimum exertion where blood samples are analyzed to study the effects of exercise on tissue metabolism.

To obtain an objective evaluation of the levels of lactic acid, pyruvic acid, and glucose in the blood after exercise, without slighting the importance of any of these three components, their relationships were studied. The basal levels of glucose, lactic acid, and pyruvic acid obtained by the methods used approximated 100, 10, and 1 mg. per cent, respectively. The average rise in lactic acid which resulted from an increase of glucose equivalent to 10 mg. per cent was equivalent to 1 mg. per cent of the lactic acid. Mild exercise increased the lactic acid in amounts proportional to the severity of the anoxic condition produced. However, the pyruvic acid increases, though proportional to the rise in glucose and lactic acid after glucose administration, did not increase after exercise as rapidly as the lactic acid. The comparison of several thousands of tests has shown that after exercise there is roughly 15 mg. per cent of lactic acid in the venous blood for each milligram of pyruvic acid.

Consideration of these relationships and of alternate methods of calculation led to the use of the following formula for the correlation of glucose, lactic acid, and pyruvic acid levels obtained five minutes after the completion of the mild stair-climbing test (described above), applied 60 minutes after the oral administration of 1.8 grams of glucose per kilogram of body weight:

$$CI = \frac{\left(L - \frac{G}{10}\right) + \left(15P - \frac{G}{10}\right)}{2}$$

where CI is called the index of carbohydrate metabolism and where G, L, and P are the levels of glucose, lactic acid, and pyruvic acid in mg. per cent, respectively.

There were two separate sets of circumstances in which the ratio of lactic to pyruvic acid became less than 15 to 1. The first was when the level of lactic acid was low in a subject in good physical condition and in a state of apparently adequate nutrition. In such a situation there was a tendency for such mild exercise to create a situation which was closer to the basal state and the ratio of lactic and pyruvic acid was closer to 10 to 1 than to 15 to 1. However, the values obtained were then low and did not affect the interpretation of the index. The other situation wherein it was observed that the lactic acid to pyruvic acid ratio tended to be closer to 10 to 1 was in subjects who were showing pronounced signs of thiamine deficiency. While this was not true in every case, a glance at the individual charts will reveal that in deficiency the tendency for the pyruvic to increase faster than the lactic acid did exist. Though this fact has apparently little value in evaluating so-called preclinical signs of nutritional deficiency, it does in a measure bear out the work of Stotz and Bessey[12], who discussed the shift in lactic to pyruvic acid ratios in pigeons in experimental thiamine deficiency. Since the relatively higher pyruvic acid figures obtained on the thiamine-deficient subjects tend to increase the index obtained in the above-described calculation, and since this is the end we should like to obtain with this calculation, the result is fortuitous rather than erroneous.

The test of the value of CI depends upon its application under experimental conditions. Figure 32 gives curves which connect the points representing the average CI obtained for each dietary group starting with March 1944. The dotted lines in the later months of the figure cover the results obtained between points when some of the subjects in a given group were being supplemented and others were still receiving a depletion diet. It should be noticed that the A group, which had already been on a diet low in thiamine for a period of nine months, started in March 1944 at a point considerably higher than the B or C groups. Though the fluctuations were marked, the A groups remained higher than the other groups until after June 1945, when the B groups were placed upon a more severely depleted regimen. The first test made on these subjects after June 1945, which was during the first week in August 1945, showed that the B groups already had higher CI's than those obtained from the A groups at the same time. This rise was very precipitous and indicates the possibility that earlier signs of metabolic insufficiency might have been found in these groups if this test had been applied in less than two months. The CI's for the B groups continued to rise until the subjects were supplemented with vitamins of the B complex. Decreases from these high values corresponded well with periods of vitamin supplementation.

The value of the interpretation of the changes in the index of carbohydrate metabolism is to a large measure dependent upon its relationship to the development of clinical signs of nutritional deficiency and its ability to predict such signs before they occur. It seems obvious that such primary changes in cellular chemistry should precede what may be the secondary alterations in nerve cell function, which in turn should be followed by the more apparent alterations in cellular structure. Should one be able to prove that, in an experimental set-up, it is possible to make an earlier prediction of nutritional deficiency than was hitherto available, the nutritional scientist would have an additional tool for future experimental work. Figures 33 and 34 give the individual curves for the subjects in the B groups and illustrate the possibility that such a tool is at hand.

It is probably significant that no subject in the B groups had a carbohydrate index above 14 at any time during the two-year period they served as controls. On the other hand every subject in the B groups attained levels which were significantly higher than 14 when they were placed upon the more severely depleted diet. It is probably also significant that the subject BO1, who had the smallest rise in the carbohydrate index, had, in the opinion of the clinician who was in close contact with these subjects, what were probably the least signs of thiamine deficiency. In consequence of these observations, whenever the combined glucose-plus-exercise test gave an index of carbohydrate metabolism above 15, that subject was placed under close observation. Within one to five months after the high carbohydrate index was obtained, the subject began to show signs of diminished response to stimulation of Achilles or patellar reflexes.

CORRELATION OF INDEX WITH CLINICAL SYMPTOMS

In Figures 33 to 36 the letters A, P, and E are abbreviations for Achilles reflex, the patellar reflex, and edema, respectively. The descending arrows associated with these figures indicate the time at which the first observation of the particular clinical phenomenon occurred. Ascending arrows associated with A and P indicate times of initial improvement of Achilles and patellar reflex responses. Since any edema present disappeared very rapidly in all cases after yeast supplementation (double lines), the times of edema recoveries are not indicated.

Subject BY1 can serve as an example for a correlation of the changes that occur in the index of carbohydrate metabolism with those that take place in the Achilles and patellar reflexes. In the period before depletion, BY1 showed greater oscillations than the average of the rest of his group. This may be associated with a rather volatile temperament which was characterized by periods of hyperactivity. The highest value obtained before diet B (the more severe depletion diet) was inaugurated on June 5, 1945, was 13.3 on February 15, 1945. Within eight weeks after the start of the depletion regimen he achieved a level of 14.5. The increase to this level was not considered significant. However on August 21, 1945 a CI of 22.9 was obtained and this was considered significant of the onset of metabolic insufficiency. Late in November 1945 signs of decrease in Achilles and patellar reflexes were first noticed. The diet was supplemented with yeast extract on December 23, 1945 and on January 10, 1946, he gave a CI value of 13.3, indicating a pronounced improvement in his ability to metabolize carbohydrate. The patellar and Achilles reflexes began to show signs of improvement in February and April 1946, respectively. The other members of the B group present similar pictures, either more or less pronounced.

Figures 35 and 36 present the individual curves for the subjects in the A groups. These curves, as mentioned previously, do not start before March 1944, when the test was developed, i.e. after the original depleted diet had been in effect for nine months. They are characterized by marked oscillations which in most cases pass through the level (15) which is the empirically established level of metabolic insufficiency for the subjects in the B groups. Two cases, AO2 and AO3, in the old group never attained levels higher than 10, indicating that they were able to make a satisfactory adjustment to the original depletion diet. Only one subject, AY5, in the young group showed any marked reflex changes and this came at a time following some of his highest levels of the index of carbohydrate metabolism. In general, reflex changes which did occur corresponded with the high levels of the CI. A more detailed discussion of the physiological variations in the A group is given in the section devoted to clinical changes.

In reviewing the above findings one might ask how these data on lactic and pyruvic acids differ from other studies on thiamine depletion. It is probably true that except for the work reported by Williams, Mason, Power, and Wilder (17) most past efforts have been expended mainly in analysis of basal lactic and pyruvic acids in the blood. The results herein reported definitely indicate that basal levels do not tend to increase until after states of severe deficiency are achieved and then not in all cases. The use of glucose to increase the load before determining lactic and pyruvic acids gives results which offer excellent correlations with some of the early signs of thiamine deficiency, but there are many cases where this test gives low results in lactic and pyruvic acid when the combined glucose-plus-light-exercise test indicates the possibility of thiamine deficiency. There have been reports of severe exercise tests in experimental thiamine-depletion studies, but it is the impression of the writers that such tests produce a condition of anoxia which completely overwhelms any slight changes that may occur in the by-products of carbohydrate metabolism as a result of diminished cocarboxylase content of the tissues. It is possible for a healthy athlete under conditions of severe exercise to achieve much higher levels of lactic and pyruvic acids than a thiamine-deficient subject. The blood for the analysis of lactic and pyruvic acids should not be drawn until at least five minutes after exercise in order for the constituents of the blood to attain a condition approaching equilibrium. The need for correcting the levels of lactic and pyruvic acid for the amount of glucose present in the blood at the time of the test has already been thoroughly discussed.

Whether or not both lactic and pyruvic acid analyses are necessary is a question which has occurred to the authors many times during the course of this work. Both are recommended in any repetition of a research problem similar to that discussed in this monograph because a more stable average effect is obtained with both than with one alone. Should anyone wish to apply this technic to a survey where economy of time and effort are important factors, it might be adequate to do just the glucose and the pyruvic acid, omitting the determination for lactic acid. The formula for the index of carbohydrate metabolism would then be, $CI = 15P - \frac{G}{10}$.

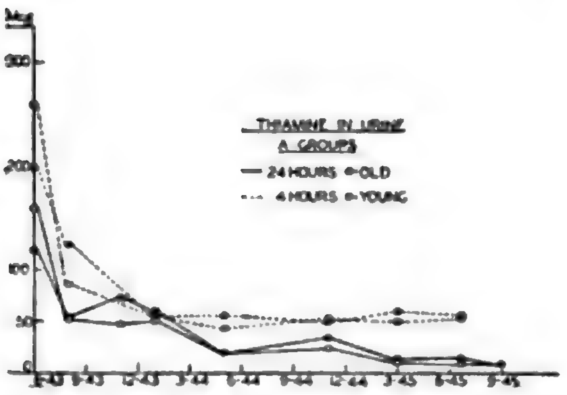


FIG. 37

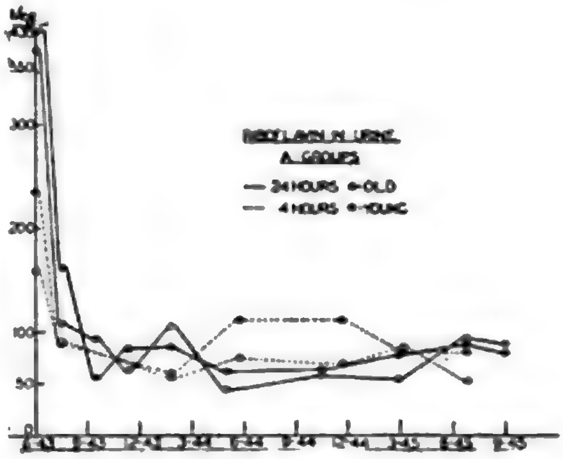


FIG. 38

FIG. 37. Excretion of thiamine in the urine of the A groups.

FIG. 38. Excretion of riboflavin in the urine of the A groups.

STUDIES ON URINARY EXCRETIONS OF THIAMINE AND RIBOFLAVIN

The examination of the urine for its thiamine and riboflavin content was undertaken in order to provide an additional check of the food intake of the subject and to attempt to learn whether urinary excretions of thiamine and riboflavin could be correlated with nutritional deficiencies. It was not anticipated that the 24-hour excretions would give more than an index of dietary consumption of thiamine and riboflavin, but it was hoped that the 4-hour urinary excretion after the administration of a test dose of 1 mg. of thiamine or riboflavin would be indicative of the apparent tissue storage of the vitamin. This test has been described by Williams, Mason, Power, and Wilder (17).

Decreases of urinary excretion of thiamine and riboflavin during dietary depletion.—Figures 37 and 38 illustrate the quantities of thiamine and riboflavin excreted in the urine of the groups ingesting Diet A, which provided approximately 400 micrograms of thiamine and 800 micrograms of riboflavin per day. It is interesting that the thiamine excretion of the A group, though quite low after two months of dietary depletion, did not reach its minimum levels even after 6 months on the regimen. Indeed there was a statistically significant decrease in the amount excreted in the third year of the diet as compared with that excreted in the first and second years (see Figure 37).

The observation of Williams *et. al.* (17) that the 24-hour excretion of subjects depleted in thiamine decreased faster than the 4-hour excretion after 1 mg. of thiamine was administered intramuscularly, was confirmed by the data obtained in the first six months of the experiment. This low level having once been reached during the first year, there was no further decrease in the 4-hour excretions.

The excretions of riboflavin in the urine (Figure 38) followed a pattern which was similar to that obtained with thiamine except that the data obtained from time to time showed greater variability. This was probably due to the fact that urinary excretions of riboflavin are very dependent on the volumes of urine excreted and it was not possible to control the urine volumes.

TABLE 12

URINARY EXCRETION OF THIAMINE ON B DIET

(B Diet Started on June 4th, 1945)

DATE	AVERAGES AND STANDARD DEVIATIONS IN MICROGRAMS			
	Old Subjects (6)		Young subjects (5)	
	4 Hour	24 Hour	4 Hour	24 Hour
3/ 1/45		2184 ±340		1930 ±660
3/ 8/45	407 ±116		375 ±231	
6/22/45		40 ±14		49 ±22
6/27/45		17 ±3		22 ±12
7/ 5/45		15 ±6		18 ±5
7/10/45	24 ±11		32 ±14	
8/31/45		8 ±2		11 ±3

Tables 12 and 13 show the urinary excretion of thiamine and riboflavin, respectively, of the subjects in the B group. These are the subjects who for the first two years of the experiment received diet A plus a supplement of yeast extract which contained approximately 6 mg. of thiamine and 1.3 mg. of riboflavin. On June 4, 1945, they were started on a diet which contained only 200 micrograms of thiamine and 750 micrograms of riboflavin. Table 12 separates the average results obtained for the old and young subjects and indicates that in less than three weeks after the diet was started, the 24-hour excretion of thiamine dropped from approximately 2000 to approximately 50 micrograms. There was practically no thiamine in the urine after three months on this depletion diet. The 4-hour excretion test, which was applied about one month after the diet was started, indicated that these subjects were depleted much more rapidly than those that had been on the A diet. This 4-hour test was not repeated with the group during the depletion period in order to avoid the possible complication of administering thiamine intramuscularly in a situation where control of the extent of the depletion was of paramount importance. The averages obtained on the 4-hour excretion tests, 24 and 32 mcg. for the old and young respectively, after only about one month on the B diet, further indicated that the rate of depletion was greater on diet B than it was on diet A, in which the average 4-hour excretion remained at approximately 50 mcg. throughout the last two years of the experiment.

The data on urinary excretion of riboflavin in the subjects on diet B summarized in Table 13 did not differ very much from data obtained on subjects in the A group. This was to be expected since the riboflavin contents of the A and B diets were very similar.

Increase of Urinary Excretion of Thiamine and Riboflavin after Supplementation.—There were not sufficient analyses done during the first two months of the study (June–August 1943) to make possible the estimation of the rate of increase of thiamine or riboflavin in the urine of the group (B) which was obtaining yeast extract at that time. Both the 4- and 24-hour excretions of this group were at or near their peak for the study after two months. However, in late 1945 and 1946 when this group was supplemented after a period of severe depletion, the opportunity again presented itself to observe the rate at which the urinary excretion of thiamine and riboflavin increased.

TABLE 13
URINARY EXCRETION OF RIBOFLAVIN ON B DIET
(B Diet Started on June 4th, 1945)

DATE	AVERAGES AND STANDARD DEVIATIONS IN MICROGRAMS			
	Old Subjects (6)		Young Subjects (5)	
	4 Hour	24 Hour	4 Hour	24 Hour
3/ 1/45		846 ±168		1121 ±143
3/ 8/45	258 ±39		272 ±85	
6/22/45		171 ±28		189 ±47
6/26/45	45 ±33		78 ±26	
6/27/45		105 ±28		111 ±30
7/ 5/45		91 ±12		85 ±15
8/31/45		82 ±14		62 ±14

Tables 14 and 15 give the 24-hour urinary excretions of thiamine and riboflavin, respectively, of some of these patients in the B group. These tables present data from urine collections taken after yeast extract was added to the regimen of the subjects who had subsisted for five months or more on a diet containing only 200 mcg. of thiamine and 750 mcg. of riboflavin. The yeast extract contained 6 mg. of thiamine and 1.3 mg. of riboflavin. The date given under each subject's identification number is the day on which that subject was started on the yeast extract. It is obvious from the data in these charts that the rate at which the urine values increase varies greatly with the individual. The data do not indicate any marked difference between the young and old subjects. Some support for the clinical practice of giving large doses of thiamine in cases in which thiamine deficiency is suspected is offered by the records of BO1, BO4, BY1, and BY4, who were relatively slow in attaining states of thiamine saturation, indicating that they might have been saturated faster with a larger dose.

TABLE 14

URINARY EXCRETION OF THIAMINE AFTER YEAST ADMINISTRATION

24 Hour Test—Mcg.

NO. OF DAYS	BO1 12/23/45	BO2 11/28/45	BO3 10/28/45	BO4 11/21/45	BO5 11/28/45	BY1 12/23/45	BY2 11/29/45	BY4 9/12/46	BY5 2/13/46
0*	7	12	5	6	9	11	13	8	16
1	21	182	—	16	—	209	287	248	—
2	39	468	—	—	134	206	330	—	—
3	112	661	290	86	259	291	414	375	776
4	—	809	—	—	349	—	—	—	—
5	386	—	456	—	—	541	575	—	879
6	—	684	—	—	476	—	667	—	—
7	—	885	—	255	502	—	—	490	1436
8	—	—	511	—	—	—	772	—	—
9	—	1045	—	348	791	—	—	—	—
10	—	—	—	—	—	—	791	742	1270
11	—	976	—	—	1298	—	—	—	—
12	638	—	—	—	—	652	1050	—	—
13	—	1222	—	601	1354	—	—	602	952
15	—	—	—	—	—	—	1178	—	—
16	623	1269	—	700	1445	—	—	814	—
20	—	—	1037	674	—	—	1120	—	—
21	—	1059	—	—	1551	—	—	—	—
23	—	1133	—	—	1121	—	—	1263	—
25	908	—	—	—	—	—	—	—	—
26	—	—	—	—	—	1668	—	—	—
27	—	—	1395	—	—	—	—	—	—
28	—	—	—	645	—	—	—	—	—
30	—	—	—	—	—	—	—	1342	—
32	1236	—	—	—	—	980	—	—	—
36	—	—	—	1333	—	—	—	—	—
38	1345	—	—	—	—	1047	—	—	—
42	—	—	1275	—	—	—	—	—	—
44	—	—	—	—	—	—	—	1652	—
45	—	—	—	—	—	1486	—	—	—

* Typical excretion before supplementation.

Tables 16 and 17 give the results of the 4-hour excretion tests after supplementation with either 6 grams of yeast extract, 6 mg. of thiamine, or 6 mg. of riboflavin. The date at which supplementation was started and the means of supplementation are given beneath the subject's identification number. Most of the data given in these two tables are on the subjects in the A group. Note that it took at least as long to saturate AO4 as BY3 with similar doses of thiamine, even though AO4's depletion period was three full years as opposed to less than one year of more severe depletion for BY3.

TABLE 15
URINARY EXCRETION OF RIBOFLAVIN AFTER YEAST ADMINISTRATION
24 Hour Test—Mcg.

NO. OF DAYS	BO2 12/23/45	BO2 11/28/45	BO3 10/28/45	BO4 11/21/45	BO5 11/28/45	BY1 12/23/45	BY2 11/29/45	BY3 4/12/46
0*	47	68	78	56	71	81	66	71
1	70	107	—	75	171	192	252	173
2	148	164	—	—	147	238	286	—
3	151	166	285	66	248	252	—	117
4	—	158	—	—	203	—	—	—
5	126	—	290	—	—	307	409	328
6	—	204	—	—	164	—	251	—
7	270	133	—	170	103	201	—	242
8	—	—	198	—	—	—	267	—
9	284	136	—	174	175	330	—	—
10	—	—	—	—	—	—	177	350
11	—	171	—	—	171	—	—	—
12	240	—	—	—	—	348	329	—
13	—	209	—	300	203	—	—	258
15	—	—	—	—	—	—	339	242
16	249	203	—	190	133	—	—	—
20	—	—	499	177	—	—	322	—
21	—	203	—	—	139	—	—	—
23	—	464	—	—	—	—	—	—
25	147	—	—	—	—	403	—	—
28	—	—	—	155	—	—	—	—
29	—	—	—	—	—	—	—	701
32	331	—	—	—	—	412	—	—
36	—	—	—	262	—	—	—	—
38	469	—	—	—	—	616	—	—
42	—	—	344	—	—	—	—	—
43	—	—	—	—	—	—	—	1046
44	—	—	—	413	—	—	—	—
45	483	—	—	—	—	656	—	—
60	—	—	—	—	—	700	—	—
84	—	—	—	—	—	—	606	—
85	—	—	—	—	605	—	—	—

* Typical excretion before supplementation.

MISCELLANEOUS BIOCHEMICAL ANALYSES

Attempts to uncover other metabolic alterations which might be useful in the diagnosis or prognosis of thiamine or riboflavin deficiency produced a considerable amount of data on a variety of tests of blood and urine. These tests did not uncover any new information that could be correlated with nutritional deficiency.

TABLE 16

FOUR HOUR THIAMINE EXCRETION AFTER SUPPLEMENTATION

(Mcg.)

NO. OF DAYS	AO4 THIAMINE 6/9/46	AO6 Yeast 5/27/46	AY4 Yeast 6/9/46	AY5 Thiamine 5/27/45	BY3 Thiamine 5/27/46
0*	33	27	83	45	6
1	35	84	138	121	52
2	74	123	230	359	49
3	—	—	—	—	—
4	78	186	192	—	174
5	—	—	—	—	—
6	91	202	352	649	—
7	—	—	—	—	—
8	115	198	364	464	196
9	—	—	—	—	—
10	—	—	—	—	—
11	81	385	291	270	270
12	—	—	—	—	—
13	—	—	—	—	—
14	—	284	—	300	242
15	154	—	336	—	—
16	—	—	—	—	—
17	—	243	—	294	195
18	142	—	166	—	—
24	—	217	—	494	214
26	103	—	401	—	—
31	—	322	—	540	299
32	260	—	333	—	—
45	—	217	—	430	472
46	165	—	322	—	—

* Typical excretion before supplementation.

Included among the list of miscellaneous analyses were studies of hemoglobin concentration, hematocrit, and erythrocyte counts. Cholesterol levels of the blood, lecithin-cephalin tests of liver function, urea clearance, plasma nitrogen partition, and serum phosphatase gave suggestions of differences between the young and old subjects, but there were no significant differences found between the different dietary groups. Occasional tests were run of creatinine and total solids in the urine to check on the technics of urine collection.

SUMMARY AND CONCLUSIONS

1. The study of the effects of glucose ingestion provided comparative data on the utilization of carbohydrate in young and old individuals. The generally accepted assumption that the rate of absorption of carbohydrate from the gastro-intestinal tract is slower in old men was not confirmed. While it is possible to explain the higher levels of lactic acid, pyruvic acid, and glucose in the blood 60 minutes after ingestion as being due to a slower utilization of carbohydrate, the relatively higher levels of glucose which are also present 30 minutes after glucose ingestion could hardly be explained entirely on the basis of slower utilization. If the older subjects absorb glucose more slowly than the young subjects, there would have been a marked difference in the comparative results obtained after giving glucose orally and intravenously (see Table 9). This was not the case.

TABLE 17
FOUR HOUR RIBOFLAVIN EXCRETION AFTER SUPPLEMENTATION
(Mcg %)

NO. OF DAYS	AO6 Yeast 5/27/46	AY4 Yeast 6/9/46	BY4 Riboflavin 5/27/46
1	119	204	69
2	126	266	188
4	128	259	—
5	214	390	504
8	99	451	328
11	286	—	312
14	243	—	714
15	—	332	—
17	239	—	474
18	—	403	—
24	274	—	585
26	—	323	—
31	264	—	520
32	—	270	—
45	229	—	456
46	—	336	—

2. That old men utilize carbohydrate more slowly than young men was frequently confirmed during the course of this investigation. Not only were the higher levels of glucose and of lactic and pyruvic acids in the blood prolonged for a considerable period after the young had returned to normal, but it was also apparent from a study of many individuals of the old group (not reported here) that there was some delay in obtaining the peak levels of lactic and pyruvic acids which in many cases did not occur until 120 minutes after glucose ingestion (without exercise).

3. The *basal* levels of lactic and pyruvic acids are of little, if any, value in esti-

mating states of nutritional deficiency. It would seem that during the early stages of thiamine deficiency the organism at rest can maintain the normal equilibrium levels of lactic and pyruvic acids, and that it is only after pronounced signs of clinical pathology have become apparent that the basal levels of lactic and pyruvic acids become elevated, and then not in every case.

4. The determination of the levels of lactic and pyruvic acids following glucose administration to individuals with variable glucose tolerance curves is of little value unless the levels of lactic and pyruvic acids are correlated with the amounts of glucose present in the blood at a given time. A large number of such determinations have demonstrated that there is a direct relationship between the amount of glucose present in the blood and the lactic acid and pyruvic acid levels.

5. The addition of a mild exercise test given 60 minutes after glucose ingestion increased the metabolic load and made it possible to demonstrate distinct differences in the metabolism of depleted subjects at an early stage in the course of their deficiency. In order to demonstrate the earliest possible cellular pathology it was best not to omit either the glucose load or the mild exercise. The extent of the chemo-pathological damage was ascertained by relating the blood levels of glucose (G) and of lactic (L) and pyruvic (P) acids 5 minutes after the exercise test to each other in accordance with the following formula:

$$\text{Index of Carbohydrate Metabolism (CI)} = \frac{\left(L - \frac{G}{10}\right) + \left(15P - \frac{G}{10}\right)}{2}$$

In the study of mild thiamine restriction (400 mcg. of thiamine per day) the index of carbohydrate metabolism oscillated considerably, indicating that the subjects on this diet were probably in a border-line state of deficiency. With the more severely restricted diet (200 mcg. of thiamine per day) the index of carbohydrate metabolism of all the subjects increased to what was apparently a pathological level in ten weeks or less. Incontrovertible clinical signs of thiamine deficiency appeared in this group within one to four months after the initial significant rise in the index of carbohydrate metabolism.

6. Attempts to correlate amounts of thiamine and riboflavin in the urine with the state of nutritional deficiency proved to be of little value except as a check of the dietary intake. Though it can be shown that an average low level of thiamine and riboflavin excretion will be obtained in consequence of the ingestion of a depleted diet, the variations which occur among individuals make the results of urinary excretion of little diagnostic significance except to assist in the evaluation of dietary consumptions during the weeks preceding the test.

REFERENCES

1. Lohman, K. and Schuster, P. H.: Untersuchungen über die Cocarboxylase. Biochem. Z. *294:* 188–214, 1937.
2. Thompson, R. H. S. and Johnson, R. E.: Blood Pyruvate in Vitamin B_1 Deficiency. Biochem. J. *29:* 694–700, 1935.
3. Platt, B. S. and Lu, G. O.: The Accumulation of Pyruvic Acid and Other Carboxyl Compounds in Beri-beri and the Effect of Vitamin B_1. Biochem. J. *33:* 1525–37, 1939.

4. Barron, E. S. G., Lyman, M., Lipton, M. A. and Goldinger, J. M.: Effects of Thiamine on Condensation Reactions of Pyruvate. J. Biol. Chem. *141:* 957–73, 1941.
5. Barron, E. S. G., Goldinger, J. M., Lipton, M. A. and Lyman, C. M.: Effects of Thiamine on Metabolism of Ketoglutarate. J. Biol. Chem. *141:* 975–79, 1941.
6. Mann, P. J. G. and Quastel, J. H.: Vitamin B_1 and Acetylcholine in Isolated Brain. Nature *145:* 856–7, 1940.
7. Hill, A. V. and Long, C. N. H.: Muscular Exercise, Lactic Acid and the Supply and Utilization of Oxygen. Ergeb. Physiol. *24:* 43–51, 1925.
8. Long, C. N. H.: Lactic Acid in Blood of Resting Man. J. Physiol. *58:* 455–60, 1924.
9. McLeod, J. J. R.: The Concentration of Lactic Acid in the Blood in Anoxemia and Shock. Am. J. Physiol. *55:* 184, 1921.
10. Beuding, E. and Wortis, H.: The Stabilization and Determination of Pyruvic Acid in the Blood. J. Biol. Chem. *133:* 585–91, 1940.
11. Lu, G. D.: Blood Pyruvate Levels in Rat, Pigeon, Rabbit and Man. Biochem. J. *33:* 774–8, 1939.
12. Stotz, E. and Bessey, O. A.: The Blood Lactate-Pyruvate Relation and Its Use in Experimental Thiamine Deficiency in Pigeons. J. Biol. Chem. *143:* 625–31, 1942.
13. Friedemann, T. E. and Barborka, C. J.: The Significance of the Ratio of Lactic to Pyruvic Acid in the Blood After Exercise. J. Biol. Chem. *141:* 993–4, 1941.
14. Chesler, A., Homburger, E. and Himwich, H. E.: Carbohydrate Metabolism in Vitamin B_1 Deficiency. J. Biol. Chem. *153:* 219–25, 1944.
15. Beuding, E., Stein, M. H. and Wortis, H.: Blood Pyruvate Curves Following Glucose Ingestion in Normal and Thiamine Deficient Subjects. J. Biol. Chem. *140:* 697–703, 1940.
16. Williams, R. D., Mason, H. L., Smith, B. F. and Wilder, R. M.: Observations on Induced Thiamine Deficiencies in Man. Arch. Int. Med. *66:* 785–99, 1940.
17. Williams, R. D., Mason, H. L., Power, M. H. and Wilder, R. M.: Induced Thiamine Deficiency in Man. Arch. Int. Med. *71:* 38–53, 1943.
18. Hoffman, W. S.: Rapid Photoelectric Method for Determination of Glucose in Blood and Urine. J. Biol. Chem. *120:* 51–55, 1937.
19. Friedemann, T. E. and Haugen, G. E.: The Determination of Keto Acids in Blood and Urine. J. Biol. Chem. *147:* 415–42, 1943.
20. Barker, S. B. and Summerson, S. W.: The Colorimetric Determination of Lactic Acid in Biological Material. J. Biol. Chem. *138:* 535, 1941.
21. Hennessy, D. J. and Cerecedo, L. R.: The Determination of Free and Phosphorylated Thiamine by a Modified Thiochrome Assay. J. Am. Chem. Soc. *61:* 179–83, 1939.
22. Najjar, V. A. and Ketron, K. C.: An Improved Thiochrome Method for the Determination of Thiamine in the Urine. J. Biol. Chem. *152:* 579–84, 1944.
23. Snell, E. E. and Strong, F. M.: A Microbiological Assay for Riboflavin. Ind. Eng. Chem., Anal. Ed. *11:* 346–50, 1939.

SECTION III

CLINICAL OBSERVATIONS

Oscar Kreisler, M.D.

Extension over a period of years was a novel feature in studies of this kind. The slow development of symptoms and signs as they might occur in the natural development of deficiency disease and the possibility of equally protracted periods of recovery offered promise of revealing new information in this field of nutritional endeavor. The clinical staff was particularly concerned with the following objectives.

1. Observation of any clinical changes occurring in the old and young men as a result either of lapse of time (ageing) or of deprivation of B vitamin complex.
2. Detection of individual and age differences of resistance to B vitamin complex deprivation in the stage of induction of deficiency, and of factors influencing the degree and speed of recovery from deficiency disease in the subsequent stage of supplementation.
3. Determination of the influence of physical activity on the development of signs and symptoms when this was possible with the subjects.
4. Correlation of mental and physical changes with the biochemical status.

It should be recalled that the members of the A group, seven old and five young subjects, were the first to be subjected to a restricted diet containing approximately 400 micrograms of thiamine and approximately 800 micrograms of riboflavin daily. The experiment started June 6, 1943.

The members of the B group, numerically equal to the A group in old and young subgroups, were fed a diet identical with that of the A group but supplemented with yeast extract. They thus served as controls until the 3rd of June 1945, when their diet was restricted more severely than that of the A group. Thiamine was reduced to approximately 200 mcg., and riboflavin to approximately 700 mcg., daily.

The physical activity of the experimental and control subjects, both old and young, could be regulated to a limited extent only. Some subjects were quite sedentary and rejected the suggestion of engaging in work. Others were fairly active. One subject paced the floor almost continuously. A number of subjects worked regularly one to several hours a day, mopping floors, washing windows, and making beds. Others, following swings of mood and ideation, worked only periodically. It required experience to recognize and to utilize their cooperative states, for often they would work only if asked and not offer their help spontaneously. No subject worked really hard or for long hours and in no case did the caloric requirement exceed by very much the (100%) basal intake of 2200.

The desirable scope of clinical investigation was narrowed considerably by the mental illness of many of the subjects, and gaps in routine examinations, especially where cooperation was necessary, were frequent. On the other hand, it was the mental illness of the subjects that permitted the protraction of the study over a period of years and this advantage partly compensated for many disadvantages.

Methods of Examination. Routine physical and neurological examinations followed conventional outlines. The subjective symptomatology, in certain individuals, appeared unreliable at times or was not disclosed at all, and tests that required the subject's sustained concentration or motor effort could not always be carried out.

In psychiatric examinations no definite schemes were used. Many of the subjects were inaccessible in certain spheres occasionally or all of the time. The individual's attitude toward his environment, his degree of alertness, his interest in himself and others, his ambitions, mannerisms, ways of thinking, orientation as to time, place, and person, his affectation and swings of mood and where they occurred, and his delusions and hallucinations were studied.

Psychological tests were made at regular intervals. The character of these tests and the subjects' responses are described in another section.

It was difficult to distinguish in the individual case between the psychopathological pattern with which the subject had entered the project, his basal behavior pattern, and features superimposed on it or changing it which developed under the influence of B vitamin complex deficiency. An opportunity to study basal mental patterns of the A group came in the preliminary period of selecting subjects and of eliminating the unfit, and the B group members were observed unaffected by B vitamin complex deficiency two years longer while they served as controls for the A group.

In the routine examinations, room temperature, barometric pressure, body temperature were recorded. Spontaneous complaints and those expressed on questioning were entered on the examination sheets. "Leading" questions could not be fully avoided, because several subjects were not inclined to talk about their sensations unless asked. As developments showed, however, suggestions rarely became the source of complaints.

The physical-neurological examination was functionally and morphologically oriented and organized into units such as integument, circulatory, digestive, motor systems, sensibility, reflexes.

In the general inspection the examiner was alert to changes of skin color, excretions, and structures. The degree of skin turgor was estimated.

Pathological changes of the lips, such as opacities, thinning, scaling, were recorded.

Gums and tongue were inspected. The subject was asked routinely whether he felt burning or any other sensation in his tongue.

The dietician recorded the reactions of the subjects to the meals served. The appetite was not judged solely on the basis of the amount of food rejected by the individual; it was estimated also by speed of eating, distractibility, and objections or other remarks made about the food. In general, one could distinguish between certain schizophrenic mannerisms and lack of appetite. However, expression of appetite had limited diagnostic value in our schizophrenic subjects, for some ate mechanically although they were in a state of disturbed metabolic function.

Disturbances of gastrointestinal motility, such as vomiting and constipation, and sensations associated with them such as nausea, feeling of choking, and epigastric pain and distress were observed.

Signs of circulatory dysfunction were looked for. Attention was directed not only to the appearance of larger vessels but also to changes of minute blood vessels such as dilatations and budding of new vessels. Routine examination of heart and vessels was complemented by orthodiagraphy and electrocardiography.

Response of heart rate (HR) and blood pressure (BP) were determined by a standardized exercise test. HR and BP were recorded with the subject in the supine position at the end of a rest period of at least 5 minutes. After this, HR and BP were again determined with the subject in the sitting position. The subject then descended and climbed twice without interruption, in about one minute, a flight of twenty-one steps. At the end of this exercise which led him directly into the examining room HR and BP were again obtained at ½, 2, 4 and 6 minutes after the exercise. Reasons for choosing this exercise test were: (1) the element of training was avoided in a stair climbing test; (2) a milder exercise would be too little exertion to bring out any circulatory insufficiency, while more strenuous exertion might overtax the individual.

Touch and localization were tested with strips of cotton, pain with a pin, temperature with test tubes filled with water of varying temperatures. Swatting the soles lightly and stroking the skin with a wooden stick were also used in routine testing.

A tuning fork C-128 was used for testing the conduction of vibration. Sense of position was tested by passive movements of the toes and by arresting them in flexion or extension.

The standardized stair climbing was used as a test for muscle power. Another test for power of the gluteal and quadriceps muscles was the squatting test. The subject had to squat as deeply as possible but without using his hands as support on the floor, ten times in 20 to 30 seconds. Strength of other muscles was tested in the established routine of letting the subject counteract the examiner's strength or weight, for example by estimating the strength of foot dorsiflexion by asking him to lift the foot against downward pressure.

Coordination was tested in the usual finger-to-nose, finger-to-finger and heel-to-knee-to-shin tests (eyes open and eyes closed). The Romberg test was given and the gait of the subject observed and described. Tremors were described as to rate, rhythm, amplitude.

Examination of cranial nerves and sense organs followed a conventional outline.

Characteristics of speech and articulation were recorded.

Tendon-periostial reflexes were routinely tested. The responses were rated as follows:

Markedly exaggerated	4
Brisk	3
Normal (average)	2
Sluggish	1
Very sluggish	½
Absent	0

Superficial reflexes of the eye and pharynx and the abdominal and cremasteric reflexes were tested. The time that elapsed from stroking the skin of the chest to the appearance of the triple response was noted and also the character of the reaction.

Tests were made for pathological reflexes such as Babinski, Oppenheim, Gordon, and Hoffmann signs.

Certain common diagnostic clinical laboratory procedures complemented the physical examinations. Orthodiagraphic films of the chest were taken in anteroposterior views, from a distance of 6 feet at the height of the inspiratory phase.

Electrocardiograms were made using leads I, II, and III, CF2 and CF4, not only after a period of rest with the subject in supine position but also after the standardized climbing test.

In basal metabolism tests the subject's full cooperation and relaxation often could not be secured.

Gastric analyses were made. The vasodilatory response to histamine in some old men was severe. Therefore the stomach contents were examined after test breakfasts consisting of tea and toast, and 0.5 mg. of histamine was injected subcutaneously only when test breakfasts yielded no free hydrochloric acid.

Complete physical and neurological examinations of the mildly restricted A group subjects were scheduled for every 6 to 12 weeks. However, any intercurrent change was recorded. Such long intervals could not be maintained in the routine examinations of the more severely restricted members of the B group. During the acute stages of deficiency disease daily careful examinations were necessary for several subjects. Orthodiagraphic, electrocardiographic, and basal metabolic examinations were made routinely every 2 to 6 months. In some members of the B group ECG tracings were repeated within several days when it seemed desirable to obtain information regarding the influence of B vitamins on ECG patterns in the early phase of recovery.

The subjects were weighed weekly, in isolated cases daily for short periods of time.

Dr. Russell M. Wilder and Dr. Ray D. Williams who together had conducted experimental B vitamin deficiency studies in recent years were in contact with the study through its entire course as clinical consultants. They were at all times completely informed of the progress of the study on the basis of their own observations and of reports, and their advice greatly aided the Elgin workers in the clinical aspects of the investigation. Dr. E. S. Guzman Barron, a member of the committee and a frequent visitor at the Elgin project, was especially helpful as consultant on clinicobiochemical phases of the study.

MILD RESTRICTION OF B VITAMIN COMPLEX

Changes in the subjects of the A group developed very insidiously and inconspicuously. In the course of the first 2 years trends were observed rather than actual significant changes. Signs and symptoms, in general, did not develop and progress in a continuous pattern. There were exacerbations and remissions of signs and symptoms, although the over-all course was progression.

Mental Activity. Mental changes came so gradually that it was difficult to know when they actually appeared. The most prominent change was a dulling of faculties involving attention, interest, ambitions, and sociability, and this change was associated with a decrease of talking and a slowing of movements. One elderly subject, AO1, who was alert, quick of movement, eager at all times to help in the first one and one-half years of the mild B vitamin complex restriction phase, withdrew from the center of activities, lost his friendliness and the briskness of his movements.

Another old member, AO4, began showing a change in behavior after 2 years. His boisterousness and inclination to impress and please the examiner subsided slowly. In a late phase of his restriction period he did not care to draw any attention to himself. However, behavior changes in other old subjects could not be ascribed to vitamin deficiency with any degree of certainty. One of the young subjects, AY5, about two and one-half years after the start of restriction of his diet appeared to be very tired but he did not show any sign of organic involvement. He then chose to lie on a bench or in bed. He preferred to be alone and was irritated when contacted. Three other subjects, AY1, AY2, AY3, belonging to the "young" group but already of middle age, seemed to age extraordinarily in the course of three years. They had looked younger than their age in the beginning of the restriction period. Towards the end of the third year these men not only looked somewhat older than their years, but they also moved more slowly, seemed to have lost much spontaneity, and were more serious and more seclusive. Similar changes were not observed in members of the B group while they received supplements of yeast extract with their diet. It is important to state that some members of the A group who showed changes in their general behavior would, under stimulating conditions, make an effort to overcome their apparent debility. In psychological tests, confronted with an immediate task, they scored higher intellectually than one would have anticipated. When left to themselves, however, they chose the path of least resistance.

Skin. In three of the five young subjects, AY1, AY2, AY3, it was observed towards the end of the restriction period that the skin became thinner and had a smoother surface. This was especially noticeable in the face and on the hands. The turgor also decreased. The face did not have the former full appearance but appeared more haggard, drawn, and pale. In the old members of the A group, who had entered the project in a state of advanced skin atrophy, an evaluation of added regressive changes of the skin was practically impossible, especially in the test for skin turgor. The result varied greatly in the same individual at a single testing. Changes of the lips developed in all young subjects and in certain old subjects. The change was characterized by dryness, wrinkling, thinning, opacities, erosions near the closure line, and, in a few subjects, detachment of the epithelium at the mucocutaneous junction in form of a fringe-like whitish cuticle.

Oral Mucosa. Tongue changes developed inconspicuously and slowly in old and young members of the A group. In six of the seven old men and in two of the five young men the margin of the tongue assumed a slick appearance. The change was more impressive in the old than the young subjects. It was realized, however, that this change was perhaps partly or altogether a feature of "natural" ageing. Enlargement of fungiform papillae near the tip and marginal indentations could be seen in all five young and in three old subjects.

Gastrointestinal Tract.—Appetite was difficult to estimate in several subjects.—Two old men were paranoid in the interpretation of their somatic functions. One, AO6, had the delusion that waste products were not leaving him. Another old man, AO7, believed that meat was harming him seriously. Both subjects, at times, rejected large portions of the food served them. AO1 ate well for about two years and then started leaving food on his plate so that his intake of food decreased rather steadily. Another elderly subject, AO5, ate poorly and his intake of food varied. Of the five young subjects only one, AY5, showed an apparent decrease of appetite. After months on the B vitamin complex restricted diet, he became a moody eater, and in the third year of B vitamin complex deprivation he appeared to force himself to eat.

Only one member of the A group, AO6, complained of constipation during the restriction period.

AY5, who was emotional at times, vomited his meal occasionally. Vomiting in his case could not be attributed to B vitamin complex restriction.

Circulatory System. AY5, in the last months of B vitamin complex restriction, often ran a slightly elevated temperature for which no cause was found and during that time often showed tachycardia and occasionally slight dyspnea on exertion. No significant acceleration of heart rate or dyspnea was observed in any other young member of the A group. Cyanosis, edema, venous congestion, bradycardia, or drop in blood pressure was not found in any of the young subjects including AY5. The impression was gained, however, that telangiectases developed in the three middle-aged members of the "young" A group especially on the ears and nose in the later stages of the B vitamin complex restriction. Of the old subjects, AO7 showed edema of the legs half a year after entering the deprivation phase. The evaluation of his case is difficult for he had advanced arteriosclerosis, severe bilateral chorioretinitis with markedly impaired vision, and he later developed carcinoma of the prostate which made the administration of large doses of stilbestrol necessary. Fall of blood pressure was noted in subjects AO3 and AO6. Typical readings for subject AO6 were:

Before B complex restriction:		
supine	systolic	110 to 140 mm. Hg
	diastolic	74 to 84 mm. Hg
sitting	systolic	110 to 140 mm. Hg
	diastolic	70 to 80 mm. Hg
Immediately after exercise:		
	systolic	118 to 138 mm. Hg
	diastolic	70 to 78 mm. Hg
After B complex restriction:		
supine		92 mm. Hg systolic and 58 mm. Hg diastolic
sitting		80 mm. Hg systolic and 52 mm. Hg diastolic
Immediately after exercise:		
		120 mm. Hg systolic and 46 mm. Hg diastolic.

Two and a half years after beginning B vitamin complex restriction the ankles of this subject became swollen. The swelling was not of pitting character. The man was never dyspneic, orthopneic, or cyanotic. AO1, who in a later stage of mild B vitamin complex restriction exhibited a convincing decrease of appetite, after three years of restriction showed slight edema of the feet. About that time he appeared and acted like a distressed, worn-out old man, though he never admitted that he was tired. No drop of blood pressure was noted in his case. His usual bradycardia persisted.

Nervous System.—AY5 near the end of the third year of the restriction period complained of a "terrific" headache. None of the other young members of the A group ever expressed complaints of pains or paresthesias that could have had significance.

None of the young or old members of the A group developed an impairment of superficial sensibility in the course of mild B vitamin complex restriction. AO2 had hypalgesia, hypesthesia, and impaired temperature discrimination on his feet even before restriction of B vitamin complex.

A sustained decrease of vibration sense could not be demonstrated in any young subject of the A group, although, on occasions, subjects AY1, AY2, AY3 showed some decrease of acuity of perception of the vibrating tuning fork on the lower extremities. Such a decrease was observed in all of the old A group members in the course of the three years. In AO1 it was manifest four months after start of vitamin restriction; in AO2, from the beginning; in AO3, to a slight degree six months after the start of the restricted dietary regimen; in AO4 to a slight degree in the beginning in the lower extremities and one and one-half years later for the first time in the upper extremities; in AO5, first in the tenth month of vitamin restriction; AO6, in the seventh month and occasionally after eight months; in AO7, on upper and lower extremities sixteen months after beginning the restriction.

Of the young A group members none showed impairment of the sense of position and movement in the course of the mild restriction period.

Only one subject in the young group, AY5, appeared to develop a great need for rest. He was running occasional slight elevations of temperature during that period. AY1, AY2, AY3 appeared tired and older in later phases of the restriction but carried on their ward work on a reduced scale. Of the old men AO1 in particular showed obvious change for he had been the liveliest in the group and always had been on his feet, alert, and ready to assist wherever help was needed. In the last months of B vitamin complex restriction he sat in his chair most of the time and never offered his assistance spontaneously. For AO6, who formerly had been a good ward worker, there also was a letdown, though less pronounced.

Neither loss of muscle power nor ataxia could be demonstrated in any of the A group members.

Subject AY5 showed diminution of tendon reflexes of the knees and ankles, but other young subjects did not show a significant drop in deep reflex activity. AO1, AO2, and AO7 showed some diminution of deep reflexes of the lower extremities and AO3 revealed a transitory loss of the Achilles tendon reflexes during the period of vitamin restriction.

Correlation of the Mental and Physical Symptomatology with the Biochemical Status.—It was hardly possible to correlate individual mental and physical changes directly with the oscillations in blood glucose-pyruvate-lactate levels (or the "carbohydrate metabolism index") early in the mild B vitamin complex restriction phase. However, towards the end of the restriction period the CI tended to remain high in some subjects who had manifested mental and physical changes.

SEVERE RESTRICTION OF B VITAMIN COMPLEX

Members of the more severely deprived B group showed changes that were predominantly acute or subacute in onset. Some of the signs, such as loss of reflex, were more gradual in their development. Not one of the B group subjects, young or old, remained untouched by the depletion. The degree of severity of the clinical picture and time of onset varied from subject to subject, these differences making it necessary to terminate the depletion period individually.

Correlations of the chemical change and clinical state of the subjects during deprivation and subsequent supplementation are presented graphically in Figures 39 to 48.

Mental Activity.—Members of the B group, both young and old, during the period of the severe B vitamin complex restriction displayed a variety of mental reactions. A young man, BY5, who formerly had displayed quickly controlled tantrums very occasionally, went into a series of blind furors after eight months of severe restriction of B vitamin complex. The rages lasted for an hour or so and recurred several times in quick succession. Signs of involvement of peripheral nerves and of severe disturbances of circulation appeared about the same time. He had previously found an outlet for his hostility in destruction of things but now threw heavy objects at persons. It was necessary to remove him from the research unit temporarily. The loss of inhibition was not so extreme in another young man, BY3, who showed a change of behavior after ten and one-half months of severe B vitamin complex restriction. His aggressiveness, which formerly had been a playful discharge of energy, changed to hostility which the examiner had never noted before. Like BY5, he became markedly uninhibited regarding sexual matters. Increased irritability developed in the other three young subjects in the course of vitamin B restriction. One of them, BY2, in a rage of paranoid coloring, reacted to his paresthesias by exclaiming: "What have you done to my legs, there are little devils running up and down them." An old man of the B group, BO4, amiable and placid while fed yeast extract became irritable soon after the B vitamin complex had been restricted. He complained repeatedly that the rice-biscuit monotony of the meals upset him greatly. When he had been on the restricted diet for about five and one-half months he showed signs of disturbed circulation and went into a furor. Another old subject, BO5, who had shown features of hypomania as well as of mild agitated depression in the two

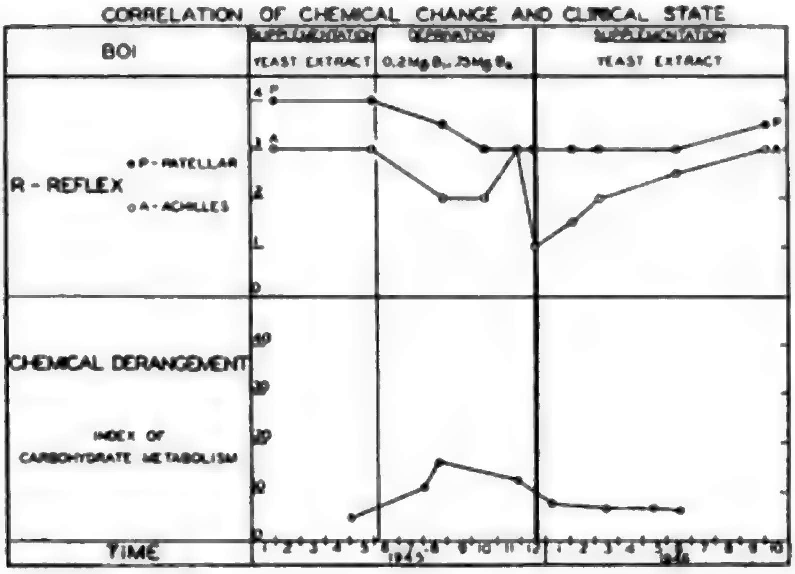


FIG. 39

years of yeast extract supplementation, after four and one-half months of B vitamin complex restriction developed the picture of typical full blown mania with marked elation, hyperactivity, and especially pressure of speech. There was evidence during this period that the physical health of the subject was impaired, for the deep reflexes had decreased and the eyelids were puffed. A third old man, BO3, became depressed and mildly confused.

Glossary of Abbreviations and Symbols in Figures 39 to 48

M: Mental
(1: Loss of emotional control, 2: Manic, 3: Paranoid, 4: Depressed, 5: Confused)
Sk: Skin
(1: Smoothening, thinning, 2: Loss of turgor, 3: Changes of the lips, 4: Angular oral lesions, 5: Seborrhoic, impetiginiform lesions, 6: Desquamation, 7: Waxy appearance (pallor & translucence), 8: Scratch effects, 9: Roughening, hyperkeratosis)
D: Digestive System
(1: Loss of appetite, 2: Constipation, 3: Nausea, 4: Vomiting, 5: Abdominal discomfort or pain, 6: Meteorism, 7: Dysphagia)
T: Tongue
(1: Atrophy of mucosa, 2: Swelling of fungiform papillae, 3: Erosion, ulceration, 4: Heavy coating)
C: Circulatory System
(1: Puffiness of facial skin, 2: Edema of legs, 3: Heaving cervical pulsation, 4: Venous congestion, 5: Cyanosis, 6: Telangiectasis, 7: Conjunctival hyperemia, 8: Corneal vascularization, 9: ECG changes, 10: Ascites, 11: Pulmonary hypostasis, 12: Hyperemia of ocular fundus, 13: Spider shaped and stellate blood vessel figures, 14: Marked tortuosity and prominence of temporal arteries, 15: Vasomotor lability, 16: Dyspnea on mild exertion, 17: Tachycardia on mild exertion, 18: Petechiae, 19: Systolic murmur, 20: Pallor, BP: Blood pressure after standardized exercise)
O: Ocular manifestations
(1: Photophobia, 2: Increased tearing, 3: Corneal opacities)
S: Sensibility
(1: Headache, 2: Pain, 3: Itching, 4: Tingling, numbness, "heat", 5: Feeling of being swollen all over, 6: Feeling of having fever, 7: Hyperalgesia, 8: Hypoalgesia analgesia, 9: Hyperesthesia, 10: Hypoesthesia, anesthesia, 11: Impaired position sense, 12: Impaired vibration sense)
Mo: Motor System
(1: Fatigue, 2: Paralysis, paresis, 3: Ataxia, 4: Loss of muscle tone, 5: Muscle stiffness, 6: Atrophy, 7: Muscle swelling)
Circling means absence of sign or symptom, e.g., C②: No edema
Underlining means: Marked, e.g., D$\underline{2}$: marked constipation
Reflexes: Right ————
Left - - - - -

Skin.—A young subject, BY3, almost a year after inception of the B vitamin complex restriction, developed a skin lesion characterized by reddening, roughening, erosion, and greasy scaling at the left corner of the mouth. From there it spread over the left cheek and assumed an impetiginiform character with formation of thick honey colored crusts. Similar changes were seen on the ears shortly afterwards. In addition, the ears appeared waxy, pale, and translucent. However, subject BY3 had shown labial and oral angular lesions in form of maceration and whitish thickening while his food was supplemented with yeast extract. In the case of BY1 slight

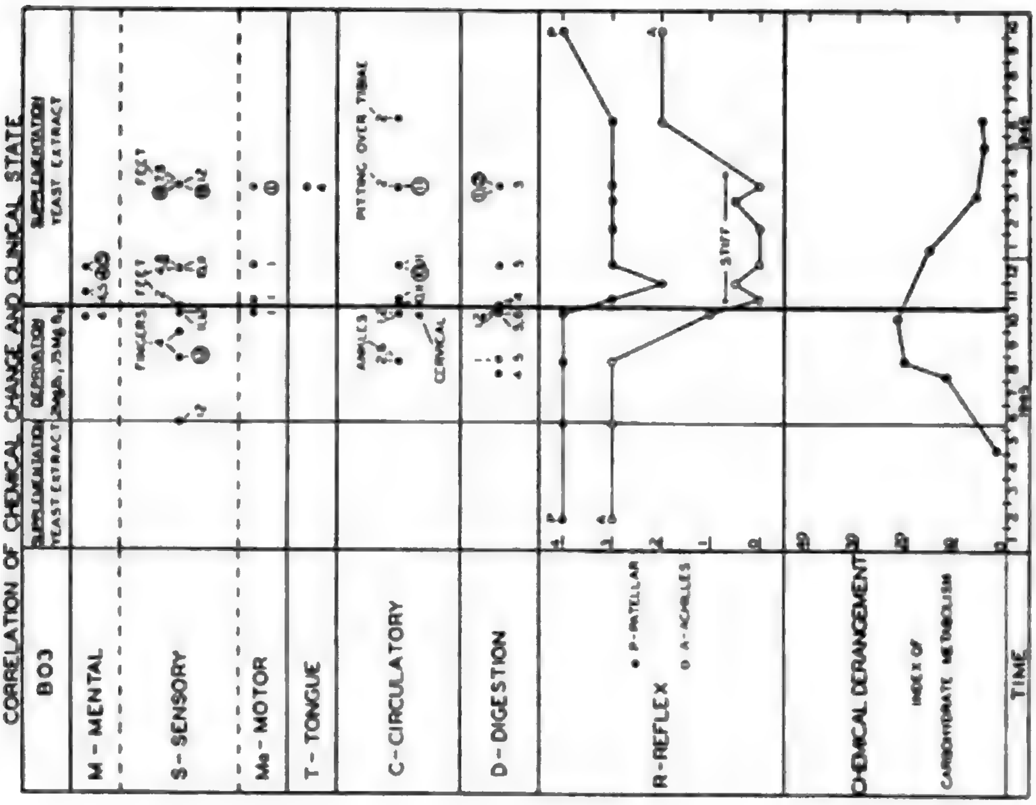

CORRELATION OF CHEMICAL CHANGE AND CLINICAL STATE
BO3
SUPPLEMENTATION YEAST EXTRACT
DEPRIVATION
SUPPLEMENTATION YEAST EXTRACT
M - MENTAL
S - SENSORY
FINGERS
FEET
Mo - MOTOR
T - TONGUE
C - CIRCULATORY
ANKLES
CERVICAL
PITTING OVER TIBIAE
D - DIGESTION
R - REFLEX
P - PATELLAR
A - ACHILLES
STIFF
CHEMICAL DERANGEMENT
INDEX OF CARBOHYDRATE METABOLISM
TIME

Fig. 41

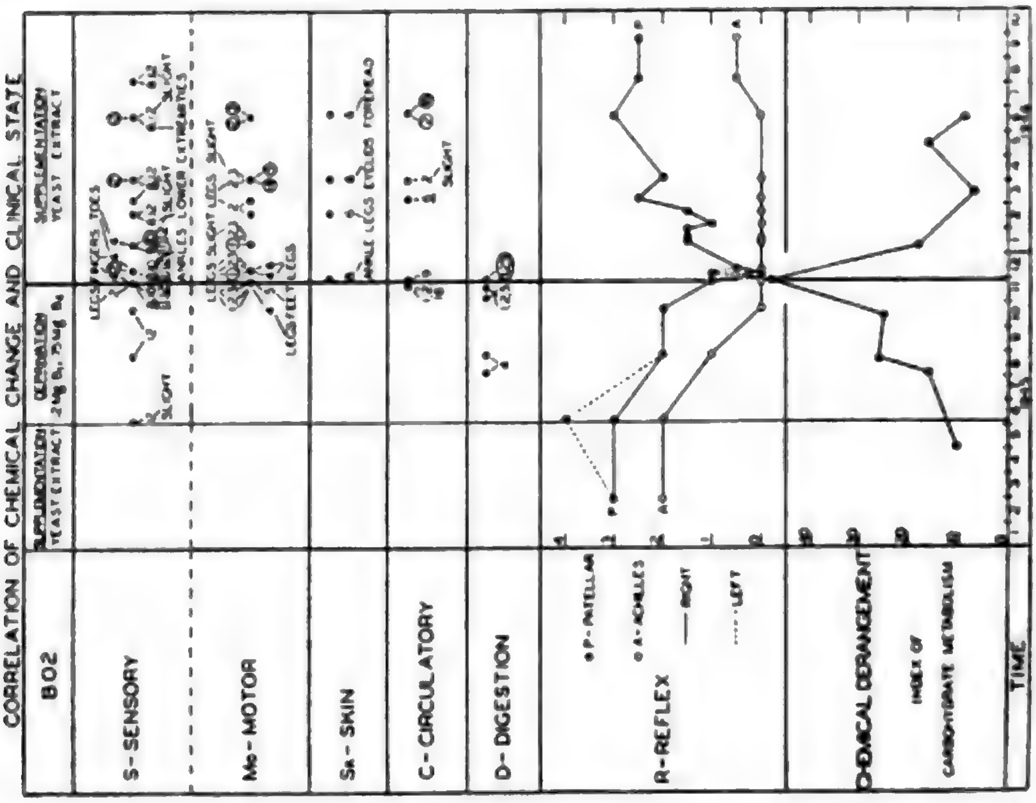

CORRELATION OF CHEMICAL CHANGE AND CLINICAL STATE
BO2
SUPPLEMENTATION YEAST EXTRACT
DEPRIVATION
SUPPLEMENTATION YEAST EXTRACT
S - SENSORY
SLIGHT
LEGS FINGERS TOES
ANKLES LOWER EXTREMITIES
Mo - MOTOR
LEGS FEET LEGS
Sk - SKIN
ANKLE LEGS EYELIDS FOREHEAD
C - CIRCULATORY
SLIGHT
D - DIGESTION
R - REFLEX
P - PATELLAR
A - ACHILLES
RIGHT
LEFT
CHEMICAL DERANGEMENT
INDEX OF CARBOHYDRATE METABOLISM
TIME

Fig. 40

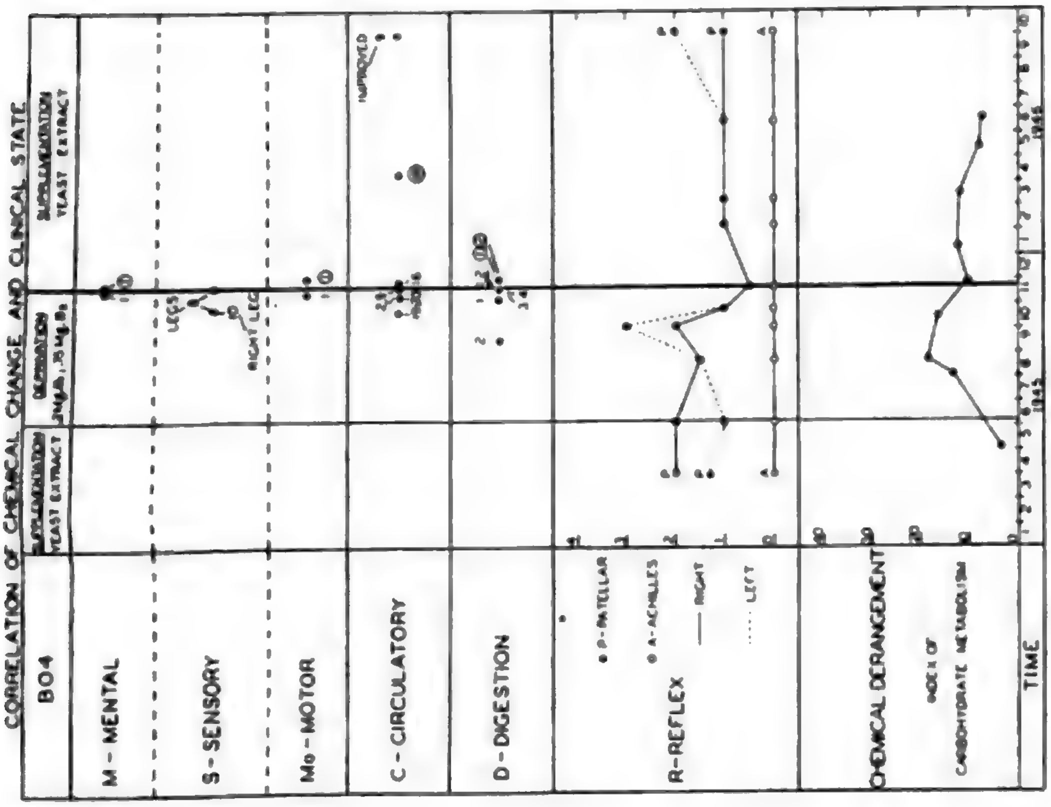

CORRELATION OF CHEMICAL CHANGE AND CLINICAL STATE
B04
SUPPLEMENTATION YEAST EXTRACT
DEPRIVATION
SUPPLEMENTATION YEAST EXTRACT
M - MENTAL
S - SENSORY
Mo - MOTOR
C - CIRCULATORY
D - DIGESTION
R - REFLEX
P - PATELLAR
A - ACHILLES
RIGHT
LEFT
CHEMICAL DERANGEMENT
INDEX OF CARBOHYDRATE METABOLISM
TIME
LEGS
RIGHT LEG
IMPROVED
1945
1946

FIG. 42

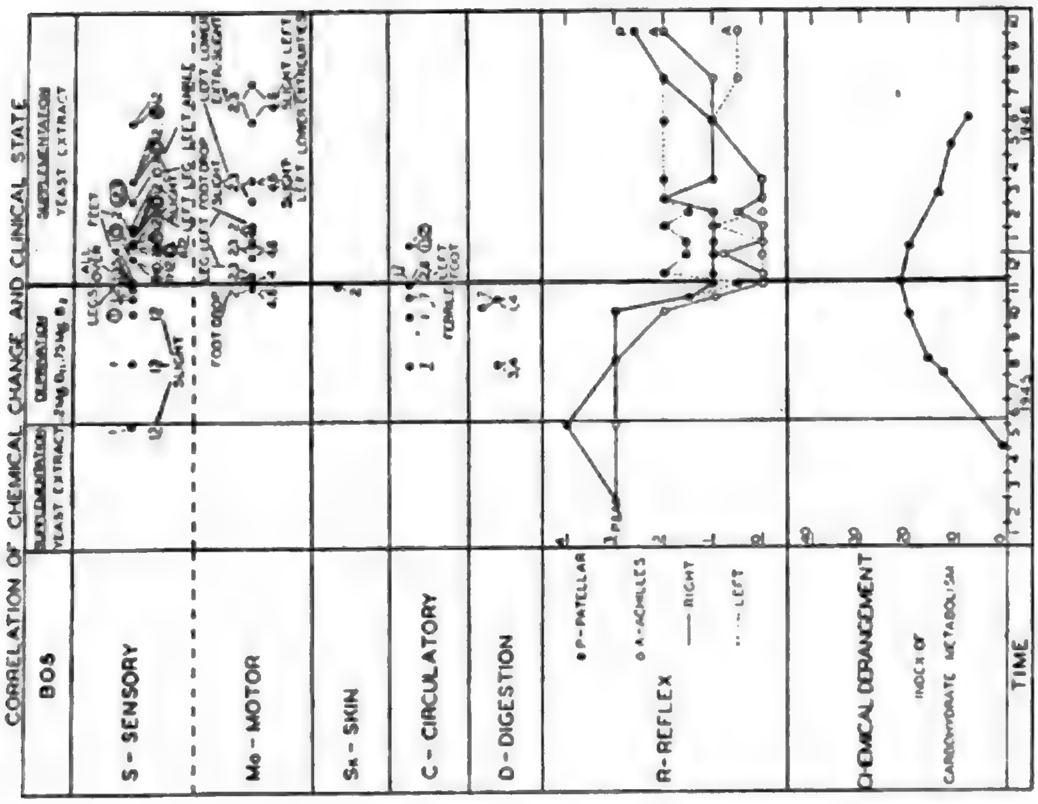

CORRELATION OF CHEMICAL CHANGE AND CLINICAL STATE
B05
SUPPLEMENTATION YEAST EXTRACT
DEPRIVATION
SUPPLEMENTATION YEAST EXTRACT
S - SENSORY
Mo - MOTOR
Sk - SKIN
C - CIRCULATORY
D - DIGESTION
R - REFLEX
P - PATELLAR
A - ACHILLES
RIGHT
LEFT
CHEMICAL DERANGEMENT
INDEX OF CARBOHYDRATE METABOLISM
TIME
SLIGHT
FOOT DROP
LEGS
FEET
LEFT FOOT
1945
1946

FIG. 43

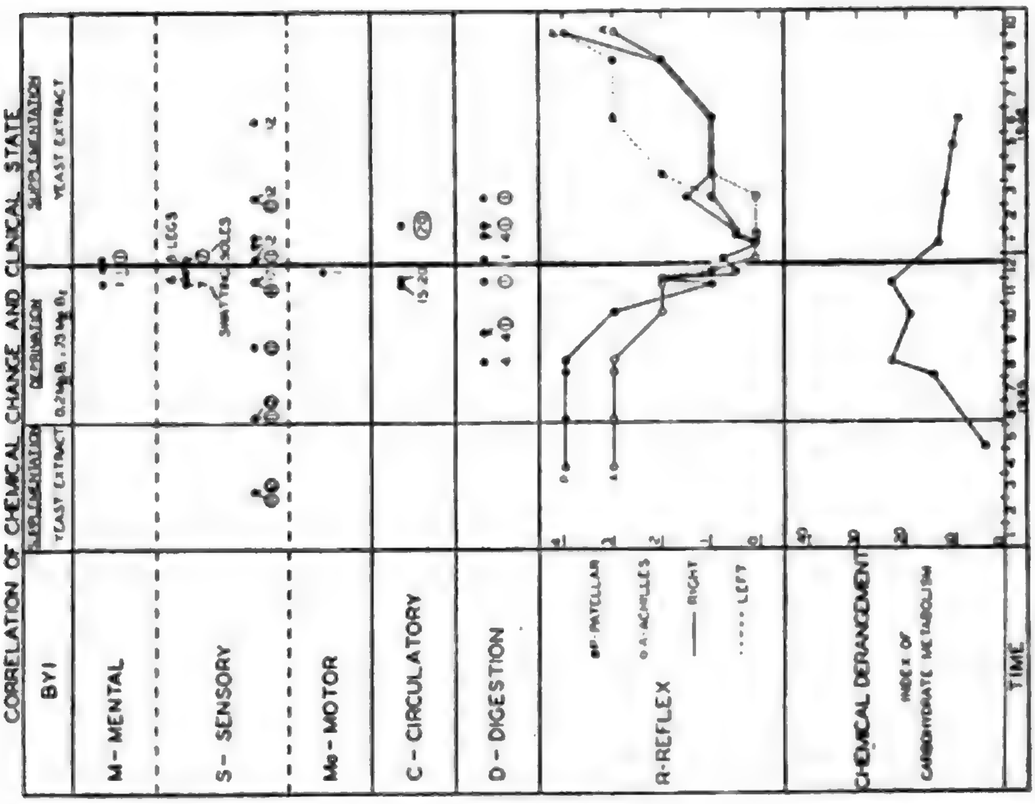

CORRELATION OF CHEMICAL CHANGE AND CLINICAL STATE
BY1
SUPPLEMENTATION YEAST EXTRACT
DEPRIVATION 0.2 mg B₁, 73 mg B₁
SUPPLEMENTATION YEAST EXTRACT
M - MENTAL
S - SENSORY
Mo - MOTOR
C - CIRCULATORY
D - DIGESTION
R - REFLEX
P - PATELLAR
A - ACHILLES
RIGHT
LEFT
LEGS
SOLES
CHEMICAL DERANGEMENT
INDEX OF CARBOHYDRATE METABOLISM
TIME

FIG. 44

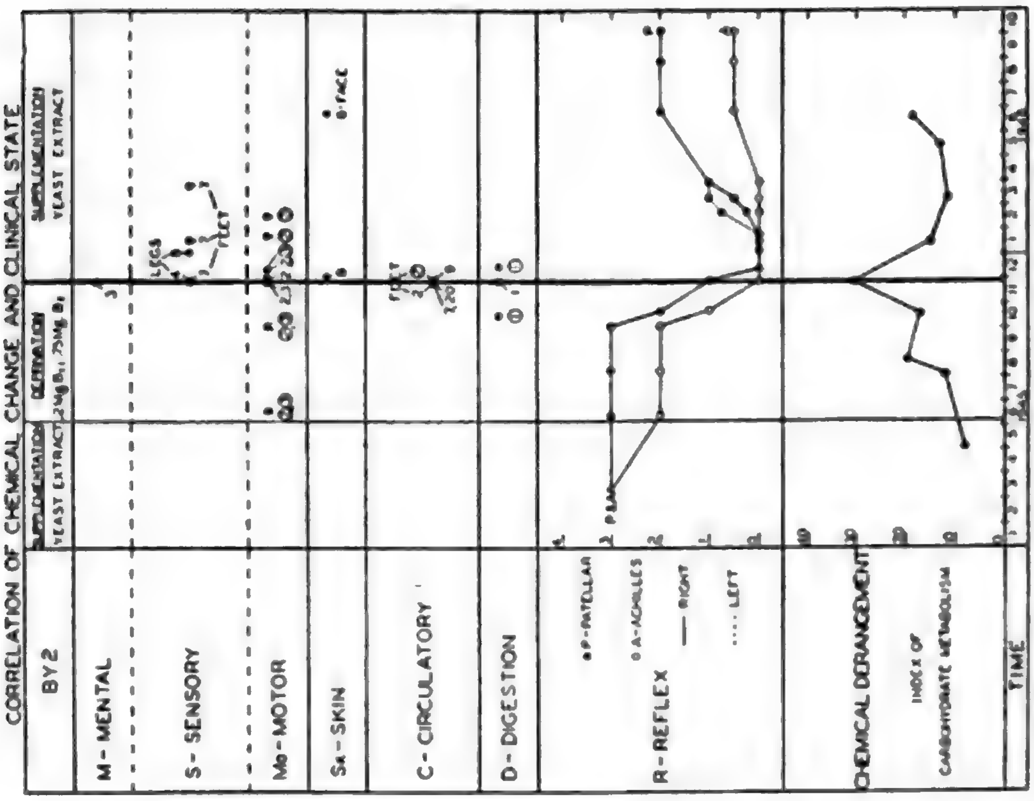

CORRELATION OF CHEMICAL CHANGE AND CLINICAL STATE
BY2
SUPPLEMENTATION YEAST EXTRACT
DEPRIVATION
SUPPLEMENTATION YEAST EXTRACT
M - MENTAL
S - SENSORY
Mo - MOTOR
Sk - SKIN
C - CIRCULATORY
D - DIGESTION
R - REFLEX
P - PATELLAR
A - ACHILLES
RIGHT
LEFT
LEGS
FEET
FACE
CHEMICAL DERANGEMENT
INDEX OF CARBOHYDRATE METABOLISM
TIME

FIG. 45

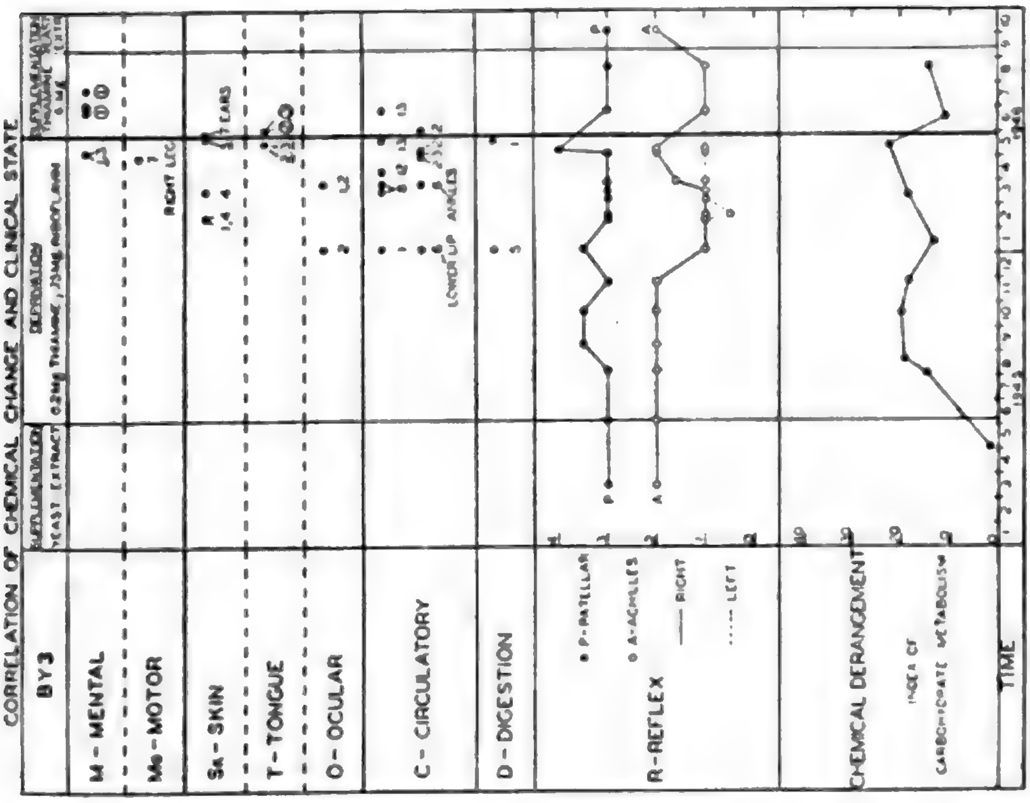

CORRELATION OF CHEMICAL CHANGE AND CLINICAL STATE
BY3
SUPPLEMENTATION YEAST EXTRACT
DEPRIVATION 0.2mg THIAMINE, .75mg RIBOFLAVIN
M - MENTAL
Mo - MOTOR
Sk - SKIN
T - TONGUE
O - OCULAR
C - CIRCULATORY
D - DIGESTION
R - REFLEX
● P - PATELLAR
○ A - ACHILLES
—— RIGHT
..... LEFT
RIGHT LEG
EARS
LOWER LIP
ANKLES
CHEMICAL DERANGEMENT
INDEX OF CARBOHYDRATE METABOLISM
TIME
1944
1945

Fig. 46

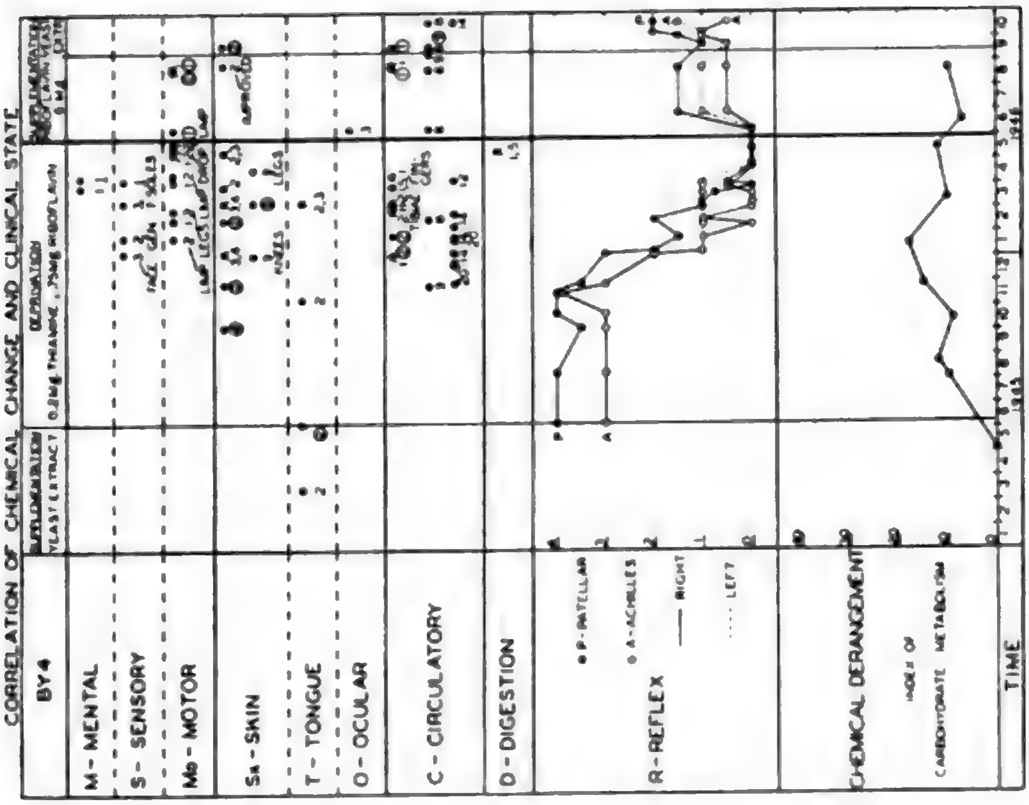

CORRELATION OF CHEMICAL CHANGE AND CLINICAL STATE
BY4
SUPPLEMENTATION YEAST EXTRACT
DEPRIVATION 0.2mg THIAMINE, .75mg RIBOFLAVIN
M - MENTAL
S - SENSORY
Mo - MOTOR
Sk - SKIN
T - TONGUE
O - OCULAR
C - CIRCULATORY
D - DIGESTION
R - REFLEX
● P - PATELLAR
○ A - ACHILLES
—— RIGHT
..... LEFT
HANDS
LEGS
CHEMICAL DERANGEMENT
INDEX OF CARBOHYDRATE METABOLISM
TIME
1944
1945

Fig. 47

pre-existing changes of the lips became more pronounced in the restriction phase. BY5 showed the development of thinning and opacities of the lips and of an angular erosion during B vitamin complex depletion. However, he had shown rhagades at the angle of mouth once in the phase of supplementation with yeast extract. BY4 developed scaling of the lips and seborrheic angular lesions. In the old subjects BO3 and BO4, senile atrophic changes of the lips seemed to progress during B vitamin complex restriction. BY4 showed roughening of the skin of the legs with the hyperkeratotic hair follicles becoming more prominent than previously.

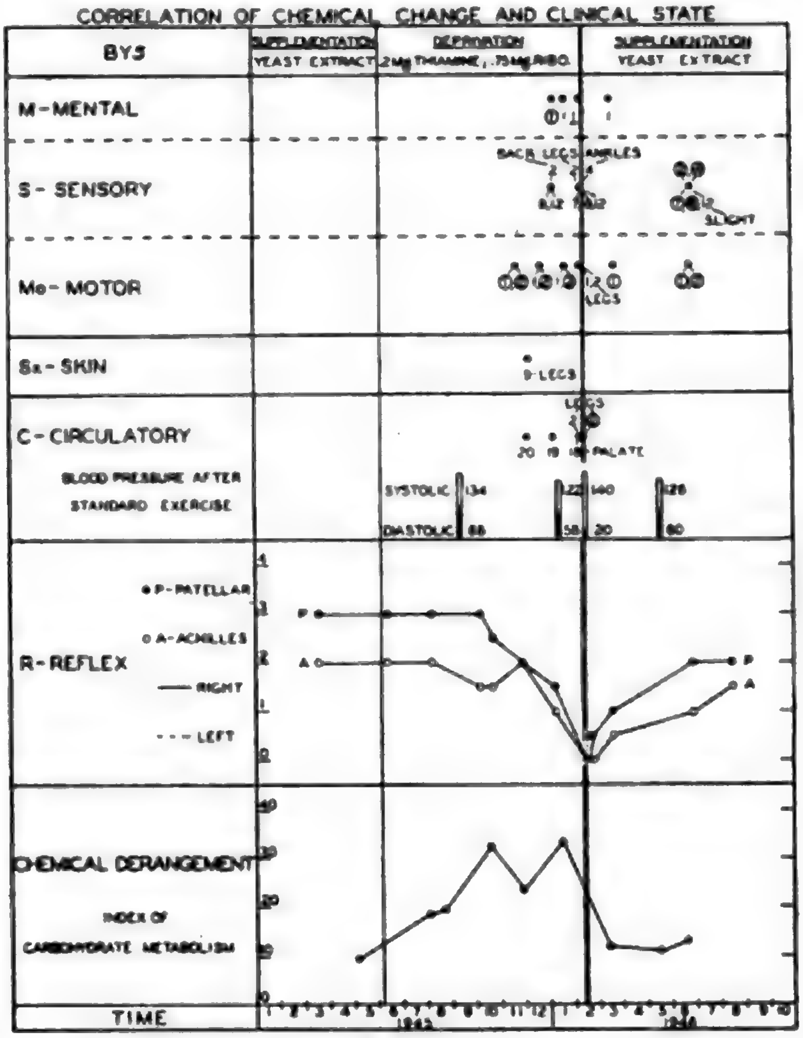


FIG. 48

Oral Mucosa.—Subject BY3, who had shown labial and angular oral lesions during the period of supplementation with yeast extract and developed an extensive impetiginiform change of the left cheek in the restriction period, also showed striking changes in the tongue nearly a year after start of B vitamin complex restriction. The fungiform papillae near the tip of the tongue became very large, pale, and translucent. A large triangular area of the anterior part of the tongue became raw-red and slick. In another young man, BY4, in addition to enlarged fungiform papillae, erosions of the tongue developed in symmetrical arrangement. No subject complained spontaneously of burning or of other painful sensations of the tongue nor could such complaint be elicited on questioning.

Gastrointestinal Tract.—The old men developed a loss of appetite earlier and more severely than did the young. There was only one old man, BO1, who in the severe restriction phase showed no loss of appetite. Among the young subjects a loss of appetite was evident in BY1. BY4, in the second half of his depletion period, indulged in phantasies of eating food not served in his diet.

Two old subjects became extremely constipated in the course of severe vitamin B deprivation. Several subjects vomited, some complained of difficulties in swallowing and retaining food and of uncomfortable sensations in the abdomen during B vitamin complex restriction. BO2 had the feeling of a tight belt about his "stomach." BO5 had "a choking, sick" feeling in his "stomach." BO3 and BY3 complained of pains in the "stomach." No significant changes were found in the gastric contents.

Circulatory System.—Although in no instance was there any decrease in total plasma protein or reversal of albumin-globulin ratios, in both old and young subjects of the B group swellings of the facial skin were observed during the period of a vitamin complex restriction. It was a swelling of non-pitting character, noted in the skin of the forehead, of the cheeks, and, most markedly, of the eyelids. With BO5 and BY4 the upper lids swelled to a degree that made them look like cushions hanging over the eyes. The skin of the forehead and cheeks when felt between index finger and thumb appeared thickened, but when released showed no pitting. This phenomenon, when first observed in subject BO5 about four months after start of restriction, was not thought to have been caused by restriction of B vitamin complex. When it was subsequently seen in other subjects the character of the facial edema was studied. Swelling of the facial skin developed as an apparently isolated sign of disturbance of tissue fluid balance. It preceded manifestations of general circulatory failure such as drop in blood pressure and edema of the legs. However, the persistent complaint in the case of BO5 during the period of facial swelling, that he felt swollen all over, was very suggestive of generalized water retention in the tissues. Such assumption was supported by the fact that while the subject lost appetite and rejected food he showed a slight transitory gain in weight. It was also noted in this case that with the development of a foot drop on the left the skin of the dorsum pedis swelled. However, with finger pressure there was no pitting. Other subjects BO2, BO3, BO4, BY3, BY5, developed swellings which were bilateral and pitting. BY3, in addition to the pitting over the tibiae, showed a unilateral swelling of the muscles of the calves. In BO3 circulatory insufficiency manifested itself first in marked edema of the legs. The heart was enlarged. There was also slight cyanosis of the lips and cervical venous congestion, but no dyspnea at rest. The exercise test appeared contraindicated. Peritoneal transudation and pulmonary hypostasis also developed. BO5 showed marked tachycardia after the climbing exercise about the end of his restriction period. BY5 seemed little affected by the restriction regimen for eight months, although in the last months of this period he interrupted his work frequently to rest in gradually extended recesses. At three months after beginning of restriction the subject showed the following blood pressure readings (see Fig. 49).

supine	systolic	130 mm. Hg
	diastolic	70 mm. Hg
sitting	systolic	128 mm. Hg
	diastolic	68 mm. Hg

Immediately after climbing exercise:

134 mm. Hg systolic
68 mm. Hg diastolic

After another three months' period the BP readings were:

supine	systolic	110 mm. Hg
	diastolic	60 mm. Hg
sitting	systolic	110 mm. Hg
	diastolic	52 mm. Hg

Immediately after exercise:

122 mm. Hg systolic
58 mm. Hg diastolic

A soft systolic murmur was heard for the first time over the apex of the heart.

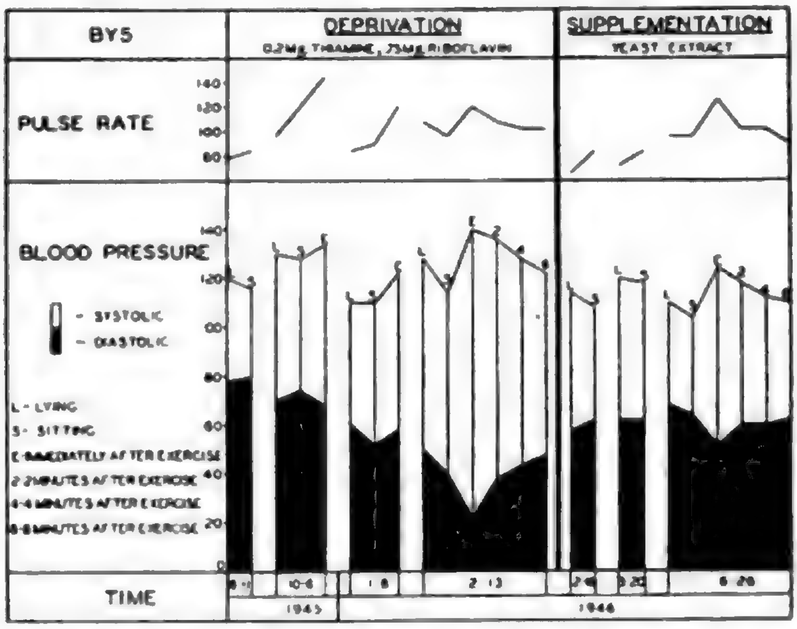


FIG. 49. Marked drop of the diastolic blood pressure of BY5 following the standardized climbing exercise, 8 months and 10 days after the beginning of B vitamin complex restriction; maintenance of the systolic blood pressure and insignificant acceleration of heart rate after exercise. Recovery under B vitamin complex administration.

Thirty-six days later the subject showed edema of the ankles, the systolic murmur was louder, and the BP readings were:

supine	systolic	128 mm. Hg
	diastolic	50 mm. Hg
sitting	systolic	114 mm. Hg
	diastolic	40 mm. Hg

Immediately after exercise readings were:

140 mm. Hg systolic
20 mm. Hg diastolic, and he was very pale.

The heart rate after exercise showed surprisingly little rise (see Fig. 49).

At the end of five and one-half months of deprivation BO2 showed marked telangiectasis about the ankles coinciding with edema. In BO4, who had always been pale, the pallor seemed to deepen and to assume a livid tinge. About six months after the beginning of the restriction his temporal arteries, inconspicuous until then, became more tortuous and markedly more prominent. Pitting over the tibia became manifest months later. BY3 had been on the restricted diet for almost eleven months when pitting over the tibia was noticeable; as in the case of BY4, puffiness of the eyelids had preceded it. In BY3, tortuosity of the blood vessels of the eye grounds, especially of the veins, was impressive. In his case ophthalmoscopy also suggested that the minute vessels of the fundus had increased in number. In addition, he developed star- and spider-shaped blood vessel figures in the skin of his chest.

Budding of blood vessels into the cornea was seen during the period of diet restriction. In the case of BY4, whose iris was of a color which contrasted with the invading vessels, fine buds with free ends appeared. Some of the vessels were carried in a delicate conjunctival fold which encroached upon the cornea. In a later phase no free ends of the vessels could be seen in the peripheral zones of the cornea; they had "looped-off" and a plexus had formed. Later, translucent opacities were observed in the limbic zones of the cornea; the conjunctival folds on the cornea could hardly be found; the vascular plexus remained.

Electrocardiographic tracings in the case of BY4 showed pronounced changes (Fig. 50). During the period of severe restriction of B vitamin complex the T waves of leads I and II showed decrease of amplitude and in lead III the T waves disappeared. In lead CF4, the T and P waves which had been upright during yeast supplementation now became inverted. Lead CF2, not taken previously, also showed T and P waves inverted. The electrocardiogram of BO4, five and a half months after inception of B vitamin complex deprivation, showed decrease of T waves in lead I. In lead II the T waves, formerly upright, were now inverted. The T in lead III also, previously upright, was inverted. In the case of BY2 lead III, previously showing upright PQRS and T, showed complete inversion of all complexes six months after the beginning of B vitamin complex restriction.

Nervous System.—Complaints of paresthesias of quite varied nature, such as tingling, numbness, itching, "heat," and "pins and needles" were heard from several B group subjects, young and old. BY1, who did not have serious impairment of physical health at any time, complained of having fever at the height of his discomfort. His skin was hot and flushed, but the body temperature was normal. BY2 gave vent to his feelings when he clamored that little devils were running up and down his legs. BY5 complained of numbness around the calves. BO2 had feelings of heat in the head and the back of the neck, burning sensations and numbness in the fingers, legs, and feet. He had the impression, he told the examiner spontaneously, that by rubbing and scratching he could alleviate the disturbance. BO3 nearly four months after the start of B vitamin complex deprivation was bothered by a numb, lifeless feeling in his fingers which made him think that he could not grip anything. Objectively, grips of the fingers of both hands were fairly strong. BO5 persistently over a period of weeks complained of itching all over and of a feeling of being swollen all over and at the end of the depletion period he also spoke of numbness in the feet.

Pain sensations, like paresthesias, were of a varied character. Burning sensations of BO2 probably reached the degree of actual pain. BO3 complained of burning in his fingers and of painful stiffness in the arches of the feet about the time he showed weakness of the dorsiflexors, and BY5 of cramps in the calves at the end of the B vitamin complex restriction phase.

Young and old members of the B group manifested disturbances of superficial sensibility. BY2, BY5, BO2, BO3, and BO5 demonstrated impairment of sensation of the lower extremities. With BY3 and BY4, in whom superficial sense qualities were apparently impaired, no unquestionable findings could be obtained because of uncooperative attitudes. With the subjects whose superficial sensibility was distinctly disturbed the sense of pain showed involvement to a greater extent than that

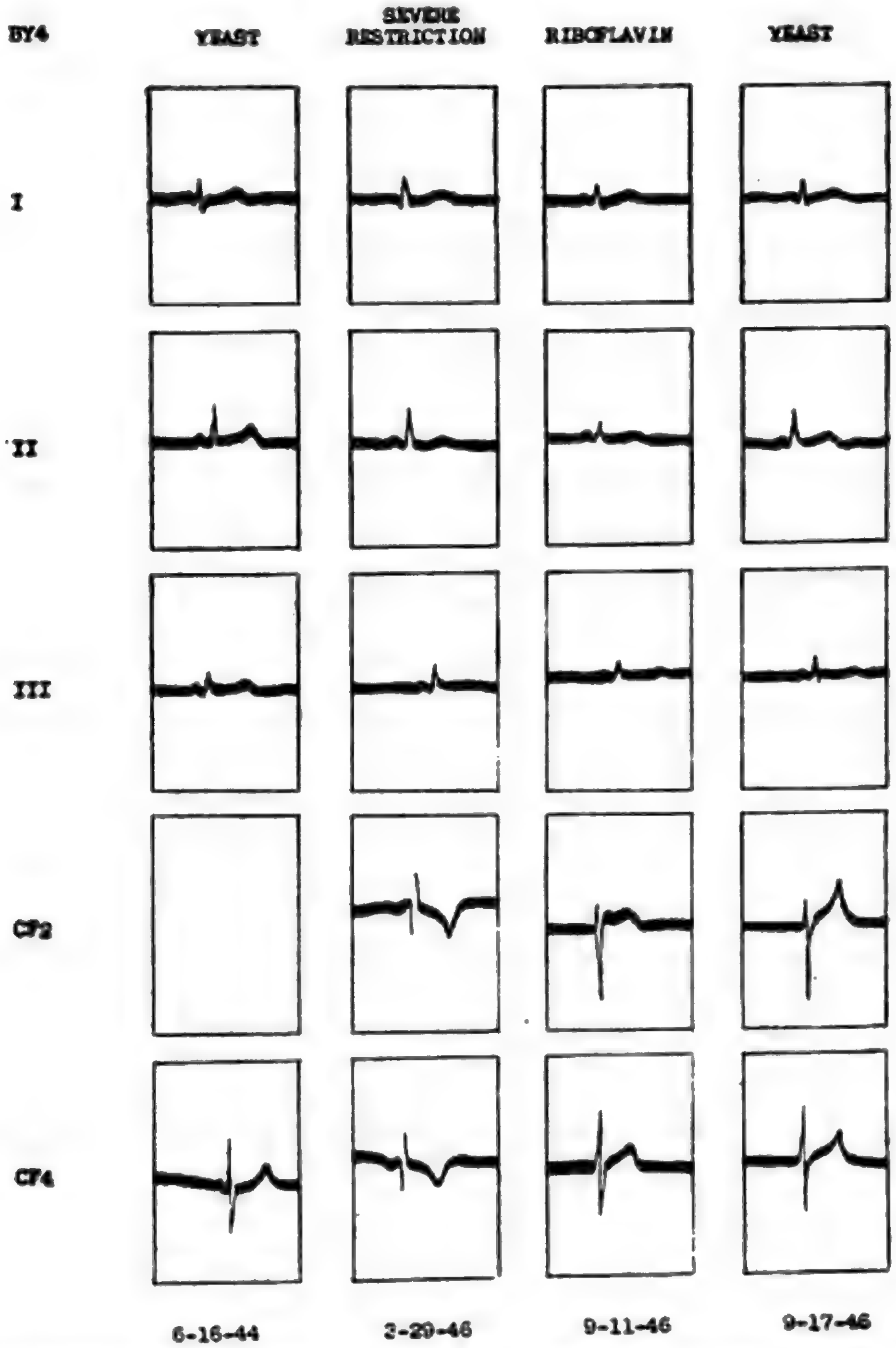


FIG. 50. Electrocardiographic changes (*Traced from original recordings*) of BY4 during period of severe B vitamin complex restriction: Decrease of amplitude of T_1 and T_2, disappearance of T_3, inversion of P and T waves in CF4. (P and T waves in CF2, not taken previously, also inverted). After 3½ months of riboflavin supplementation T_1 and T_2 more pronounced and T_3 visualized. T waves in CF2 and CF4 upright, ST segment in CF2 elevated, P waves in CF2 and CF4 absent. After 5 days of yeast extract supplementation T_1 and T_2 as tall as in the predepletion phase, T waves in CF2 and CF4 very tall and peaked, descent of the ST segment to the isoelectric line.

of light touch. Areas of hyperalgesia as well as patches and band-shaped zones of analgesia were found. Temperature sense also was impaired. An interesting observation with BY2 was the loss of perception of pain induced by pin prick as contrasted with the increase of pain response when the skin of the same area was stroked with a wooden stick.

In all of the old subjects of the B group, decrease in the acuteness of the vibratory sense was observed in the two years of B vitamin complex supplementation that preceded the severe restriction period. Although slight, these changes appear to detract from the value of the findings in the old A group members (mild restriction). However, since two factors, ageing and vitamin restriction, were influencing vibration sense in the old men, the degree of diminution that separated the groups indicated the role that B vitamin complex deprivation played in this field of sensibility. There seemed to be a "speeded-up" diminution of vibration sense in BO2, BO3, BO4, and BO5 when they underwent severe B vitamin complex restriction, reaching in BO4 the degree of almost complete loss. In the young group, BY1 and BY5 showed definite dulling of vibration sense during the restriction period. BY2 and BY3, uncooperative in sensibility tests most of the time, also seemed to have a decrease.

Among young and old subjects of the B group, impairment of position sense was not found in the predepletion phase. During B vitamin complex restriction position sense was found impaired in the lower extremities of BO2, BO3, BO5.

Deep pressure on the relaxed calf muscles seemed to evoke increased pain in BY1, BY3, BY5, BO2, and BO5 in late stages of the restriction period.

All of the young members of the B group showed signs of fatigue during the restriction period. BY1, who had paced the floor almost continuously, began reducing his activity five months after the start of B vitamin complex restriction and sat on his chair for hours. BY2 also slackened in his work and was not urged to keep it up. BY4 in the first half year of restriction participated in the ward activities, more as an onlooker than as a worker, but he then retired and insisted on lying on his bed where for months he spent most of the day. BY5, about five and one-half months on severe restriction of B vitamin complex, began to interrupt his morning work to rest and in the following three months gradually extended the rest periods, which became more and more frequent. BO1, who had never worked before or after the start of B vitamin complex restriction, was the only old subject who showed no signs of fatigue during his (six and a half months') restriction period. BO4, who had always put in one-half to one hour's work in the morning, had to give this up.

Pareses of the lower extremities were seen in young and old subjects. BO2 exhibited a conspicuous bilateral steppage gait about five and one-half months after start of restriction. BO5 at about the same time developed foot drop on the left side. His foot prints revealed the left sole totally flattened, the right arch being almost fully preserved (Fig. 51). In BY2 strength of dorsiflexion of the foot was found impaired. These three subjects had difficulties climbing stairs. They were incapable of assuming the squatting position, even halfway, and putting their hands on the thighs helped them very little. BY5 also, when neuropathy set in, had difficulties squatting.

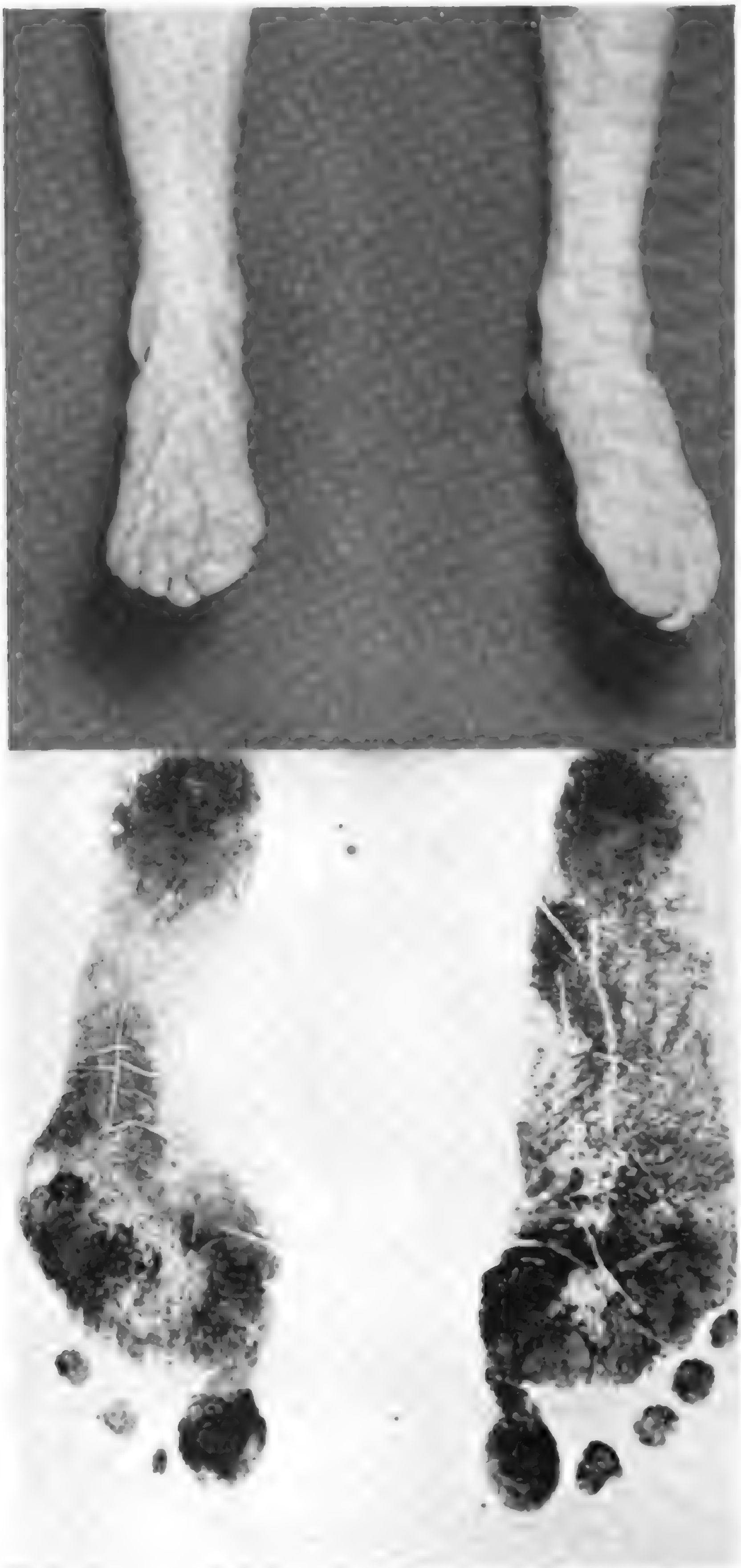


FIG. 51. Unilateral foot drop and loss of plantar arch, first observed in BO5 5½ months after inception of B vitamin complex restriction. After 11 months of yeast extract supplementation foot still in slight drop position and arch still flattened.

Muscles of the left paretic leg of BO5 atrophied somewhat. A significant difference in circumference of the calves between right and left legs developed.

Subjects BY2, BO2, and BO5, nearly six months after the start of restriction had, in association with loss of proprioceptive faculties, ataxia of the lower extremities which was demonstrated in the heel-to knee-to shin test and in an ataxic component of the disturbed gait. In the squatting tests these individuals complained of having lost the sense of balance.

In all subjects of the B group there was decrease or loss of deep reflex responses. In BY1, BY2, BY4, and BY5 complete abolition of the knee and ankle jerks and distinct diminution of the deep reflexes of the upper extremities could be observed. In BY3, no impairment whatever was seen in the patellar reflexes, but the Achilles tendon reflexes dropped distinctly. Among the old subjects, B vitamin complex deprivation led to considerable diminution of the Achilles tendon reflexes in BO1, to loss of the patellar and Achilles tendon reflexes in BO2 and BO3, to diminution of the patellar reflexes in BO4 whose Achilles tendon reflexes never could be elicited, and to loss of the Achilles tendon reflexes and marked diminution of the patellar reflexes in BO5. In the cases of BO4 and BY4, exaggeration of deep reflex activity preceded the diminution.

CORRELATION OF MENTAL AND PHYSICAL SIGNS AND SYMPTOMS WITH THE BIOCHEMICAL STATUS

With the approach of mental and physical changes during the severe B vitamin complex restriction period the blood pyruvate and lactate rose, especially in samples of blood taken after the exercise, and kept on rising until, about the time of the termination of B vitamin complex depletion, they reached their peak. All the subjects of the B group revealed this relationship of clinical to biochemical findings. It is best demonstrated when one synchronizes, graphically, the tendon reflexes in their downhill course with the rise of the "carbohydrate metabolism index." (See synaptic graphic charts of individual subjects of the B group, Figures 39–48.)

INTERCURRENT COMPLICATIONS

An epidemic of acute gastrointestinal disease occurred which required the use of sulfasuxidine. Two subjects (AO2 and AO7) developed carcinoma of the prostate. One subject (BO6) died of a subarachnoid hemorrhage and another subject (BO7) died from cerebral vascular trauma.

OBSERVATIONS DURING THE PERIODS OF RECOVERY FROM DISTURBANCES RESULTING FROM B VITAMIN COMPLEX RESTRICTION

The B vitamin complex deprivation phases were terminated by addition of B vitamin supplements to the diet. The following table shows that supplementation was fractional in several cases, starting with thiamine in five instances and with riboflavin in one. In the other subjects immediate administration of yeast extract terminated the deficiency periods.

Resumption of B vitamin supplementation ending restriction periods

AO7	5/26/45		Yeast extract
BO3	10/28/45		" "
BO4	11/21/45		" "
BO2	11/28/45		" "
BO5	11/28/45		" "
BY2	11/29/45		" "
BY1	12/23/45		" "
BO1	12/23/45		" "
AO1	12/23/45		" "
AO5	12/23/45		" "
BY5	2/13/46		" "
BY3	5/27/46	Thiamine	
	9/12/46		" "
BY4	5/27/46	Riboflavin	
	9/12/46		" "
AY5	5/27/46	Thiamine	
	9/12/46		" "
AO6	5/27/46		" "
AY1	6/ 6/46	Thiamine	
	9/12/46		" "
AY2	6/ 6/46		" "
AY3	6/ 6/46	Thiamine	
	9/12/46		" "
AO3	6/ 6/46		" "
AY4	6/ 9/46		" "
AO4	6/ 9/46	Thiamine	
	9/12/46		" "

RECOVERY FROM DISTURBANCES CAUSED BY "MILD" B VITAMIN COMPLEX RESTRICTION

Mental Changes.—The "young" subjects AY1, AY2, and AY3, who had shown diminution of psychomotor activity during the deprivation phase, became lively and more interested in their environment. AY1, though not admitting any improvement, smiled more readily when contacted and, when asked to do certain things in addition to his slow, monotonous daily routine swabbing, complied and did not display the resentment that he had shown in the last months of B vitamin complex deprivation. AY2 also became more cheerful and remarked eleven days after start of yeast extract feeding: "The last week or so I have felt pepped up." AY3 showed only a little improvement after beginning of thiamine administration and the little cheerfulness he exhibited had a resigned, melancholy quality. AY5, after the start of thiamine administration appeared to become more energetic and ready to do ward work which he had greatly resented previously. His face lost the dejected, strained expression it had shown up to the reversal and he also became more sociable in that he tolerated people around him again. Hardly any improvement could be noted in AO1's behavior under yeast extract feeding for almost a year but then the former quickness, energy, and alertness came back, although not fully. AO4 under thiamine administration showed partial return of his former boisterousness and eagerness to please. He was aware of improvement. Having taken thiamine for nearly three months he stated: "I have been more ambitious and lively again for four weeks or more. . . ."

Skin.—Changes of the skin seemed to show no improvement in response to B vitamin complex administration in the five months that followed the termination of restriction. However, skin turgor tests indicated improvement. In old subjects, as was mentioned before, loss of turgor could hardly be evaluated, nor could possible recovery be estimated with fairness. Atrophic changes in the skin grossly showed no reversibility in the recovery phase.

Oral Mucosa.—Regressive changes in the tongue as manifested in slickness of the surface especially at the margin showed no improvement. Slight enlargement of fungiform papillae and marginal indentations were still seen in the supplementation phase.

Appetite.—AY5 showed improvement of appetite. In subject AO1 return of appetite came after many months of supplementation with B vitamin complex.

Circulatory System.—The slight elevations of temperature, tachycardia, and slight dyspnea on exertion observed in the case of AY5 did not recur after the start of B vitamin complex supplementation. Subject AO1, four months after termination of his restriction period by administration of yeast, still showed slight swelling of the feet. AO6, also, four months after start of B vitamin complex administration, appeared not fully recovered and showed slight swelling of the legs. His blood pressure readings revealed a slight rise but no return to predepletion levels.

Nervous System.—There was evidence of only slight improvement of vibration sense in members of the A group—only old men had shown definite diminution in the rather coarse tests with the tuning fork—following the start of B vitamin complex supplementation.

Improvement of deep reflex activity in old men was distinct. It could be observed in the Achilles tendon reflexes of subjects AO1, AO3, and AO4. No improvement was noted in AO5 and AO6.

Fatigue subsided quickly in subject AY5 when B vitamin complex was given. Subject AO5, who had appeared very tired in the last months of vitamin B restriction, recuperated quickly after the reversal. It must be noted, however, that in addition to yeast he received sulfonamide for the treatment of his urinary infection.

Correlation of Disappearance of Signs and Symptoms with the Biochemical Status.—Improvement in the mental and physical condition of the A group members was, in general, accompanied by smaller carbohydrate metabolism index figures. The CI showed a subsequent rise where clinical improvement seemed to persist as in the case of AO5, but the rise did not go to a deficiency level.

RECOVERY FROM DISTURBANCES CAUSED BY SEVERE B VITAMIN COMPLEX RESTRICTION

With the termination of the restriction period by vitamin supplementation, return of certain lost functions was spectacular in the majority of the B group subjects.

Mental Changes.—Most striking was a recovery of feeling of well-being where it had been lost. BY5, who in the last days of the B vitamin complex depletion period had been in a serious rage beyond any control from within, was able to regain inhibition after the resumption of yeast extract feeding. BY1, who had appeared sleepy and subdued with occasional outbursts of temper in the last weeks of B vitamin complex deprivation, with provision of yeast extract quickly recovered his former alertness and willingness to work. BY2, who had been irritable and distressed over paresthesias in his legs near the end of his B vitamin complex restriction phase, became jovial and cooperative within a few days of yeast extract administration. BY3, whose supplementation started with thiamine and was extended to yeast extract three and one-half months later, relaxed quickly under the administration of thiamine, stopped indulging in obscenities, and became more friendly and cooperative. BO4's marked irritability subsided literally overnight upon resumption of yeast supplementation. BO3 overcame his depression slowly with the return of circulatory compensation under bed rest and yeast extract medication.

Skin and Mucosal Changes.—BY3 within several days after start of thiamine supplementation showed healing of severe tongue lesions, clearing of the face from impetiginiform dermatitis, and disappearance of a fissure in the lobe of the ear. The singularity of the case makes the distinction between *post hoc* and *propter hoc* very difficult. The rapidity of healing without local treatment suggests the latter.

Appetite.—Improvement of appetite where it had decreased was rapid, appearing within several days in almost all instances.

Gastrointestinal Tract.—Nausea and vomiting did not recur during B vitamin complex administration, except in the case of BY1, a very emotional subject.

The severe constipation of BO4 was abolished quickly under supplementation. It took BO3 several weeks to correct his constipation.

Circulatory System.—BO3 was also slow in his recovery from circulatory failure, which had set in four and one-half months after the start of B vitamin complex deprivation. This apparently slow response to yeast extract may be based on the advanced stage of decompensation and also on cardiac damage existing prior to the B vitamin complex restriction. This subject in the predepletion phase had shown evidence of hypertensive-arteriosclerotic disease with periods of cardiac arrhythmia and features of paralysis agitans as well. He had relatively high levels of sugar and pyruvate-lactate in the blood. The disappearance of dependent edema was rapid with bed rest. However, ascites persisted for weeks. The case was complicated by pulmonary infection.

Edema of the ankles disappeared overnight in BO2, BO4, BY2, and BY5. When these subjects became ambulatory after several days of yeast extract administration and bed rest, edema did not recur.

When BY5 showed the severe drop of diastolic blood pressure after the climbing exercise, it was not considered advisable to repeat the test within the next days. After several weeks of B vitamin complex supplementation the diastolic blood pressure after exercise was normal (Fig. 49) and the systolic murmur that had become audible during the period of restriction disappeared.

The non-pitting swelling of the left foot of BO5 disappeared under bed rest within 24 hours before yeast administration was started. However, it recurred and remained for several days when walking was permitted after two weeks of B vitamin complex supplementation. No facial puffiness was seen in this case during B vitamin complex administration.

Resupplementation began with riboflavin for BY4, and with thiamine for BY3. Before yeast was administered to these subjects they showed occasional puffiness of the eyelids.

The lividity of the skin observed in BY4 during the restriction period disappeared with riboflavin supplementation. The pallor persisted; this man had always been pale.

Telangiectasis which had been observed on the legs of BO2 decreased in the months of resupplementation with yeast extract, but also the stellate and spider-shaped blood vessel figures seen on the chest of BY3 appeared smaller; after supplementation with thiamine, the caliber of the fine vessels narrowed.

In the case of BO5, blood vessels which had invaded the limbic zones of the corneae recessed after restoration of yeast extract. The corneal vascularization of BY4 did not disappear in three months of riboflavin administration, but some narrowing of the minute vessels and some withdrawal towards the periphery seemed to take place. Further slight improvement appeared to follow full B vitamin complex supplementation, but after a month of yeast administration the finest vascular plexus still could be seen in outermost zones of the corneae.

In the electrocardiograms of BY4, after three and one-half months' riboflavin supplementation, T_1 and T_2 waves were more pronounced than they had been during B complex restriction and the T waves in CF2 and CF4 which had been inverted were again upright. The ST segment in CF2, however, showed marked elevation over the isoelectric line and T_3 was yet hardly visible. The day after this ECG had been taken BY4 received yeast and in five days T_1 and T_2 returned to predepletion amplitude. T_3 reappeared distinctly, the T waves in CF2 became taller, the ST elevation in CF2 disappeared.

The ECG in BO4, did not appear fully returned to predepletion pattern after ten months of feeding yeast extract. T_1 was smaller than it had been originally. T_2 appeared upright again but lower in voltage than it had been before B vitamin complex restriction started. Wave T_3, which had become inverted during the restriction period, remained inverted. The QRS complexes in lead II and III showed smaller amplitude than formerly in the predepletion phase.

Nervous System.—Irritative phenomena such as pains and paresthesias subsided within several days to a few weeks under B vitamin complex administration. Perception of pain in response to pin prick, wherever it had been lost, returned in weeks to months. Vibration sense showed slow return. Strength of muscles of paretic limbs showed, in general, quick restoration. BO2 showed complete recovery from his steppage gait within the first month of yeast supplementation. The unilateral foot drop of BO5 seemed in the first few months of B vitamin complex administration to be on the road to quick recovery, but then improvement slackened and after eleven months of yeast intake this subject showed the left foot slightly dropped in supination. Foot prints revealed the arch completely flattened (Figure 2).

Ataxia in the cases of BY2 and BO2 showed quick therapeutic response to yeast extract. In the case of BO5 slight ataxia of the left lower extremity was still demonstrable eleven months after resumption of yeast feeding.

Reactivity of tendon reflexes of the lower extremities, which, in general, had suffered earlier and more profound damage distally than proximally, showed a poorer recovery of the Achilles tendon than of the patellar reflexes. Several subjects who had received yeast extract for eleven months, showed only slight return of the ankle jerks. BY4, who had lost patellar and Achilles tendon reflexes completely and had shown no evidence of them during a period of over one and a half months on frequent re-checks, regained both, bilaterally, during riboflavin supplementation, though not to the degree of briskness they had shown in the predepletion period.

Correlation of Mental and Physical Signs and Symptoms with the Biochemical Status.—Just as impressive as the relationship of the mental and physical decline to the rise of the carbohydrate metabolism index during the severe restriction period was the association of clinical improvement during the supplementation period with the fall of the carbohydrate metabolism index. Again the correlation is illustrated best on individual graphic charts. The cases BO2, BO5, BY2, and BY5 are striking examples.

SUMMARY OF CLINICAL OBSERVATIONS

Mild restriction of B vitamin complex (thiamine 400 mcg., riboflavin 800 mcg., in a 2200-calorie diet presumed to be adequate in all other respects) led to physical and mental changes in chronically psychotic, mostly sedentary, old and young male subjects.

The important physical changes were regressive changes in the skin, impairment of appetite, lowering of blood pressure, slight edema, dulling of vibration sense, and diminution of deep reflex activity.

The predominant mental changes were decrease of psychomotor activity, dulling of attention, loss of interests and ambition, and seclusiveness.

The development of both mental and physical signs and symptoms was exceedingly slow. No definite claim of changes could be made in the first year of the experiment.

There was a difference in the resistance of the age groups in that only old subjects showed signs of (mild) circulatory insufficiency. The nerve involvement also was more pronounced and more persistent in old subjects during the period of mild restriction.

The therapeutic response to yeast extract administration was, in general, rather prompt as to feeling tone, interests and appetite, but rather slow, though distinct, as to deep reflexes, and hardly noticeable as to regressive skin changes except for slight return of lost elasticity.

Severe restriction of vitamin B complex (thiamine 200 mcg., riboflavin 750 mcg., in a 2200-calorie diet presumed to be adequate otherwise) led to severe physical and pronounced mental changes in another group of rather sedentary, chronically psychotic old and young patients.

The main physical changes were signs and symptoms of circulatory insufficiency, of neuropathy, of disturbed gastrointestinal motility, loss of appetite, and changes in the appearance of the tongue and skin.

The mental changes were chiefly characterized by loss of inhibitory emotional control, paranoid trends, manic or depressive features, and confusion.

Both physical and mental changes were acute to subacute in onset; within several months from the start of restriction the emotional manifestations were explosive in character.

The development of physical and mental changes correlated well in the individual case with rise of pyruvate and lactate in the blood, especially in blood samples taken after exercise (carbohydrate metabolism index).

The therapeutic response to yeast extract administration was dramatic as to appetite, circulation (in most cases), gastrointestinal motility, appearance of the tongue, certain aspects of sensibility (pains and paresthesias), and general display of energy. The recovery from loss of muscle power was rather prompt where there was no outright paralysis. Some sensory qualities showed slow return. In one case of unilateral foot drop the improvement was exceedingly slow. Slowest was the recovery of lost Achilles tendon reflexes.

Noteworthy is the return of completely abolished patellar and Achilles tendon reflexes in one young man during riboflavin administration.

Correlation of clinical improvement with fall of pyruvate-lactate blood levels in the recovery period was as striking as clinico-biochemical correlation had been in the period of severe vitamin B restriction.

COMMENTS

In a discussion of these findings comparisons should be made with observations in other recent B vitamin restriction studies.

Ray D. Williams and coworkers conducted a study (1) in which the intake of thiamine was restricted to an average of 450 mcg. (220 mcg., per 1000 calories) daily in young to middle aged female subjects who had previously suffered from psychotic episodes. Changes of attitude and behavior, diminished inclination to perform accustomed tasks, and decrease of ability to make social adjustments were observed as early signs in the subjects after eight to twelve weeks. Irritability, agitation, depression, and anxiety were also noted. The subjects complained of headache, backache, sleeplessness, tenseness, paresthesias, sensitivity to noise. Tolerance to exercise was affected. Muscles were found weak and tender. Episodes of nausea, vomiting, and epigastric distress occurred, and constipation was common. Lowering of the basal metabolic rate was seen. There were cardiovascular disturbances such as lowered blood pressure, vasomotor instability, pallor, marked tachycardia on moderate exertion, arrhythmia, electrocardiographic changes, and precordial pain. Elevations of pyruvate blood levels accompanied clinical exacerbations.

This variety of signs and symptoms is in contrast to the "apparent adequacy" for at least several months of 0.23 mgm. of thiamine per 1000 calories as reported by Ancel Keys and coworkers (2) on the basis of their observations in young healthy men. In a subsequent study by Keys *et al.* (3) a basal diet providing an average, per 1000 calories, of 0.185 mg. of thiamine, 0.287 mg. of riboflavin, and 3.71 mg. of niacin, with other members of the B complex more or less in proportion, and an average of 3300 calories per day, failed in four young men to have effect on pulse rate during and following both endurance tests and brief exhausting work, Harvard "physical fitness" test scores, strength, psychomotor functions, heart size, electrocardiograms, gastric emptying, basal metabolism, glucose tolerance, sensory and intellective functions, and a variety of objective personality evaluations, in 161 days. It appeared, however, that the thiamine intake was on the borderline of inadequacy as indicated by elevated blood pyruvate.

Keys and coworkers, in an attempt to reconcile absence of changes in their studies with findings of Williams and others, question whether the thiamine requirement is proportional to calories. They also point out that, if it is permissible to make calculations on the basis of non-fat calories, results are less discordant because there was proportionally more fat in their diet.

The experience of the Elgin study indicates that in a study of borderline intake a claim for adequacy of the diet must not be made unless the investigation is extended over a period of years.

Regressive changes of the skin observed in middle aged and old subjects undergoing "mild" B vitamin complex restriction had the semblance of features of ageing (4). The only very slight degree of therapeutic response of these changes to B vitamin complex administration during an observation period of several months prohibits the definite conclusion that they were caused by vitamin restriction. It is conceivable, however, that long protracted "mild" B vitamin complex restriction will lead to inconspicuous though hardly reversible changes.

Marked dependent edema, facial puffiness, and serous effusion, as seen in the severe B complex restriction study, have no parallel in the investigations of Williams *et al.* and Keys *et al.* Factors that contributed to the development of these features among the subjects of this study may have been, first, the fact that the restriction was not so severe that it forced early disruption of the experiment, and second, use of the rice diet. It should be mentioned, however, that K. O'Shea Elsom (5) saw the development of edema of the upper and lower extremities in experimental B vitamin complex deficiency. The edema observed by Elsom was uninfluenced by administration of thiamine or riboflavin but disappeared after the administration of yeast.

Disturbance of autonomic vasomotor control as evidenced by flushing and turning pale was, in all probability, the basis for the strange tortuosity of blood vessels seen in two of the young subjects.

Corneal vascularization as observed and described in detail in this section was almost identical with pictures shown by V. P. Sydenstricker *et al.* (6). There was no conclusive evidence, in the Elgin study, that riboflavin deficiency was exclusively the cause of the formation of the new blood vessels. Nor could it be proved that the development of spider-shaped and stellate blood vessel figures seen in one subject had its origin in riboflavin restriction.

Although the first subjects to show changes in the severe restriction phase were old men and the last subjects were young men, the small number of experimental subjects does not permit the generalization that old people will under severe B vitamin complex deprivation break down faster or more seriously than young individuals.

The old man who in more than six months of severe restriction showed little more than diminution of deep reflexes was the one who, at all times, exercised the least

This supports the view that physical activity has a precipitating effect on the development of deficiency disease.

Many features of the circulatory and nervous deficiency syndromes of these subjects had a close resemblance to the symptomatology of Oriental beriberi as found in Vedder's classic descriptions (7) and as observed quite recently by Hibbs (8).

It may be stated conclusively that synthesis of B vitamin complex factors in the body (9) did not prevent deficiency disease in any one of the severely restricted subjects.

REFERENCES

1. WILLIAMS, R. D., MASON, H. L., SMITH, B. F. AND WILDER, R. M.: Induced thiamine (vitamin B_1) deficiency and the requirement of man. Arch. Int. Med. *69:* 721–738, 1942.
2. KEYS, A., HENSCHEL, A. F., MICKELSEN, O. AND BROZEK, J.: The performance of normal young men on controlled thiamine intakes. J. Nutrition *26:* 399–415, 1943.
3. KEYS, A., HENSCHEL, A. F., TAYLOR, H. L., MICKELSEN, O. AND BROZEK, J.: Experimental studies on man with a restricted intake of the B vitamins. Am. J. Physiol. *144:* 5–42, 1945.
4. WEIDMAN, F. D.: Ageing of the skin. Ch. 14, Problems of Ageing. Biological and Medical Aspects E. V. Cowdry, 2nd Ed. Baltimore, Williams & Wilkins Co., 1942.
5. ELSOM, K. O., LEWY, F. H. AND HEUBLEIN, G. W.: Clinical studies of experimental human vitamin B complex deficiency. Am. J. Med. Sc. *200:* 757–764, 1940.
6. SYDENSTRICKER, V. P., SEBRELL, W. H., CLECKLEY, H. M. AND KRUSE, H. D.: The Ocular manifestations of ariboflavinosis. J. A. M. A. *114:* 2437–2445, 1940.
7. VEDDER, E. B.: Beriberi. New York, William Wood & Co., 1913.
8. HIBBS, R. E.: Beriberi in Japanese prison camp. Ann. Int. Med. *25:* 2, 1946.
9. NAJJAR, V. A. AND HOLT, L. E., JR.: The biosynthesis of thiamine in man and its implications in human nutrition. J. A. M. A. *123:* 683–684, 1943.

SECTION IV

NEUROLOGICAL OBSERVATIONS

Erich Liebert, M.D.

Collateral with the clinical tests presented in the preceding section, many tests were performed for the purpose of studying various factors which might be involved in the process of ageing and also for detecting early symptoms of vitamin deficiency. These studies were directed chiefly to investigations of the peripheral neurones since it is known that sensory and vascular changes in the periphery may accompany vitamin deficiency and also may play a role in the process of ageing. The tendon reflexes of older persons are not as active as those of younger people unless in the latter an upper motor neuron lesion is a complication. Reflex activity in general seems to be diminished; for example, the pupillary light reflex is slower and the amplitude of contraction of the pupil is diminished in older subjects as compared with those of younger persons.

In B vitamin deficiency the loss of deep reflexes, especially of the Achilles tendon but also of the patellar tendon reflexes, have been described and reports on sensory changes and paresthesias in the extremities in vitamin deficiency are numerous.

These studies were designed to develop an experimental technic which would permit collection of data as objective as possible. Except for the sensory tests only passive cooperation of the patient was needed.

Special apparatus was designed and built for some of these tests and in other studies the apparatus available at Northwestern University Medical School, Department of Nervous and Mental Diseases, was used.

The following examinations were performed during the period of vitamin restriction.

1. Measurements of vibration sense.
2. Measurements of tendon reflexes.
3. Test of acuity of hearing.
4. Speed and extent of contraction of pupils.
5. Tests of resistance of skin to electric current.
6. Studies of capillary beds of nails.
7. Plethysmographic studies.
8. Tests of strength.
9. Flicker fusion tests.

Only the results of the first four tests are reported in detail, since the technic used in other experiments was not well established or the results were equivocal.

I. EFFECT OF B VITAMIN COMPLEX RESTRICTION ON SENSE OF VIBRATION IN LEGS

Orientation concerning methods of testing.—It is known that the perception of vibratory stimuli in older people is diminished and the threshold much lower than in younger persons. This has been shown by Pearson (1) who examined a group of patients between the ages of 20 and 60 years, measuring the length of time during which the vibration of a tuning fork of 128 double vibrations could be perceived. The time varied in these patients from an average of 8.2 time units over the left external malleolus in the second decade of life to 2.2 time units in the seventh decade. These patients were chosen at random from a general hospital population and from a neurological service of a general hospital. Some patients suffering from Parkinsonism or a hemiplegia were included in this group and the loss of vibration sense was the same in patients suffering from these disorders as compared with other patients of the same age group. According to Pearson it appeared that the impairment of the vibratory threshold of the older subject was due to a deficient blood supply to the spinal cord on the basis of a generalized arteriosclerosis.

While this author used a tuning fork method, Yacorzynski and Brown, (2) Goodfellow, (3) and Aring and Frohring (4) measured the threshold of vibration sense with an oscillating device. These authors also kept the frequency constant, using the amplitude of the instrument as the determining factor.

It obviously is also possible to keep the amplitude constant, using a constant change of frequency as measure for testing the vibratory threshold. Goodfellow used this method and came to the conclusion that in the same person on different occasions the perception for frequency varied to a great extent, even when the person tested did not have any involvement of the nervous system. Goodfellow's patients were normal individuals.

The writers have used this method of testing changes in frequency, although aware of Goodfellow's objections. However, it was thought that because of the severe impairment of function expected it might be possible to evaluate any definite loss of vibration sense. If these frequencies would be constantly diminishing, definite conclusions as to the involvement could be drawn.

The literature seems not to provide data concerning the diminished threshold of frequency apperception in the older persons in contrast to younger men and, except for the statement that sense of vibration becomes lost, no figures are reported concerning the effect of vitamin deficiency. It is known that in many diseases usually regarded to be associated with a deficiency, like subacute combined degeneration of the cord, a loss of the vibratory sense occurs fairly early during the illness, often before any other symptoms are apparent. It was, therefore, thought to be of value to examine various vibratory frequencies in a group of patients to be subjected to a deficiency of the B vitamin complex and to study the effect of a deficiency as well as of a vitamin supplementation on the threshold of vibration sense.

Apparatus and Procedure.—The unit for activating the stimulating pointer consisted of a vacuum tube oscillator, a 3-stage radio amplifier, and an electric dynamic speaker. This apparatus gave a sinusoidal wave over a wide range of frequency. The dynamic loud speaker was tested against a beat frequency oscillator and during the examining period was rechecked from time to time against the tone from a piano. The frequencies ranged between 75 and 2000 per second.

Two points of stimulation were used, namely the external malleolus of the left foot and the soft part of the left big toe. The first point was stimulated with a small metal disk measuring ½ inch in diameter, while the soft part of the toe was stimulated by a dull-pointed metal bar.

The left foot of the subjects, either the malleolus externus or the big toe, was lightly held against the stimulator without exerting any pressure.

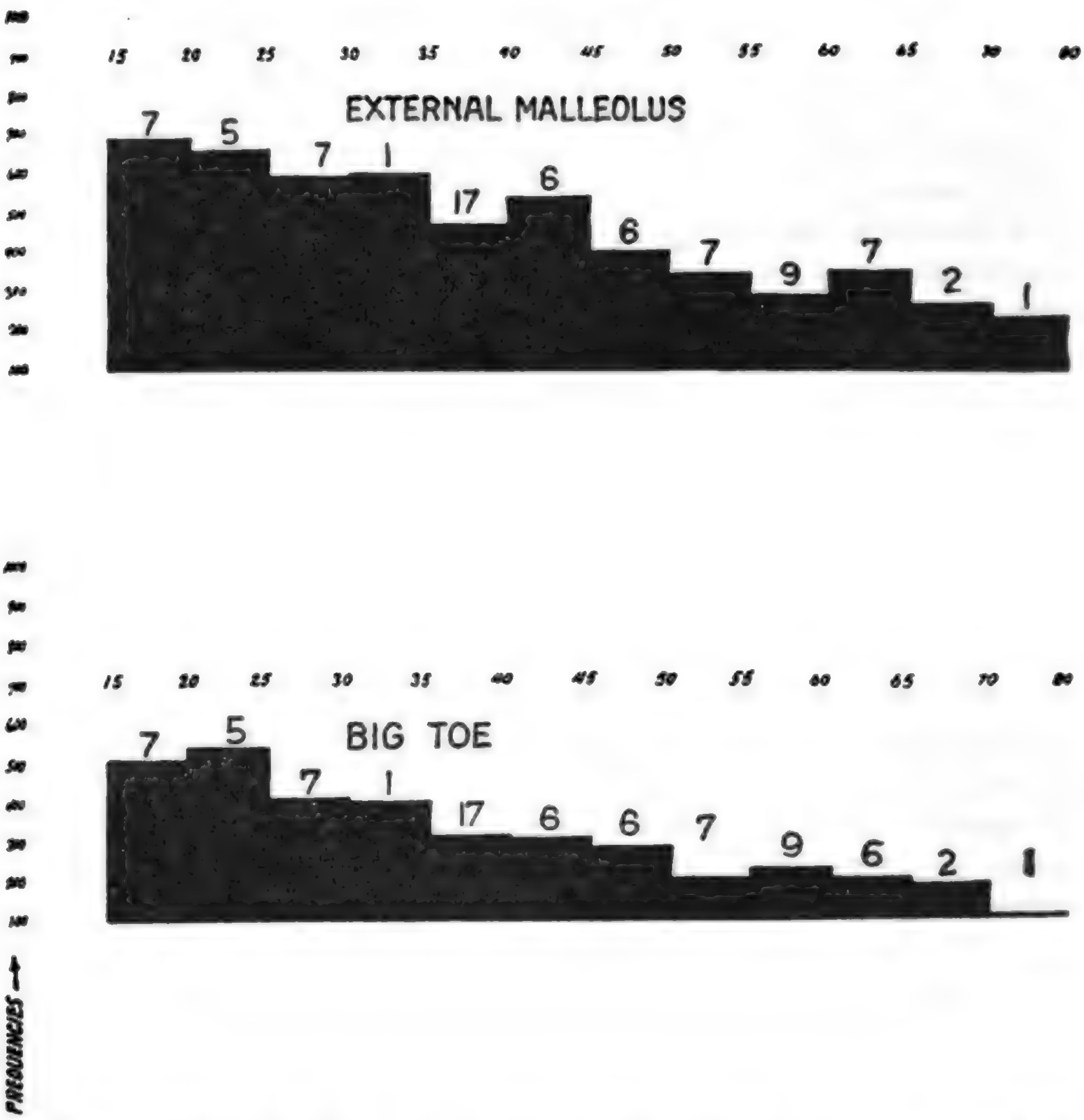


FIG. 52. Threshold of vibration sense on unselected patients of various age groups ranging from 15 to 80 years. There is a gradual decline with advancing ages. The numerals on top of the blocks indicate the number of patients in each of the age groups.

In subjects who were cooperative it was rather easy to determine the threshold of vibration sense. Two values were used:

1. Frequency was increased to a point where vibration could not be felt any longer.
2. Frequency was decreased from a point where no vibration was felt to a point where vibration could be felt.

Several determinations were made during each test, and the result was recorded only when a definite and constant threshold value could be established. Some of our patients did not cooperate sufficiently, so that no readings could be made.

In order to insure adequate attention, the patient and examiner were alone in the room. The examining conditions were kept the same. The temperature of the room, however, varied considerably as did the skin temperature. Patients with an edema of the foot or with obvious vascular disturbances in the lower extremities were not tested. The younger group of patients included in the study were too uncooperative to be used as controls.

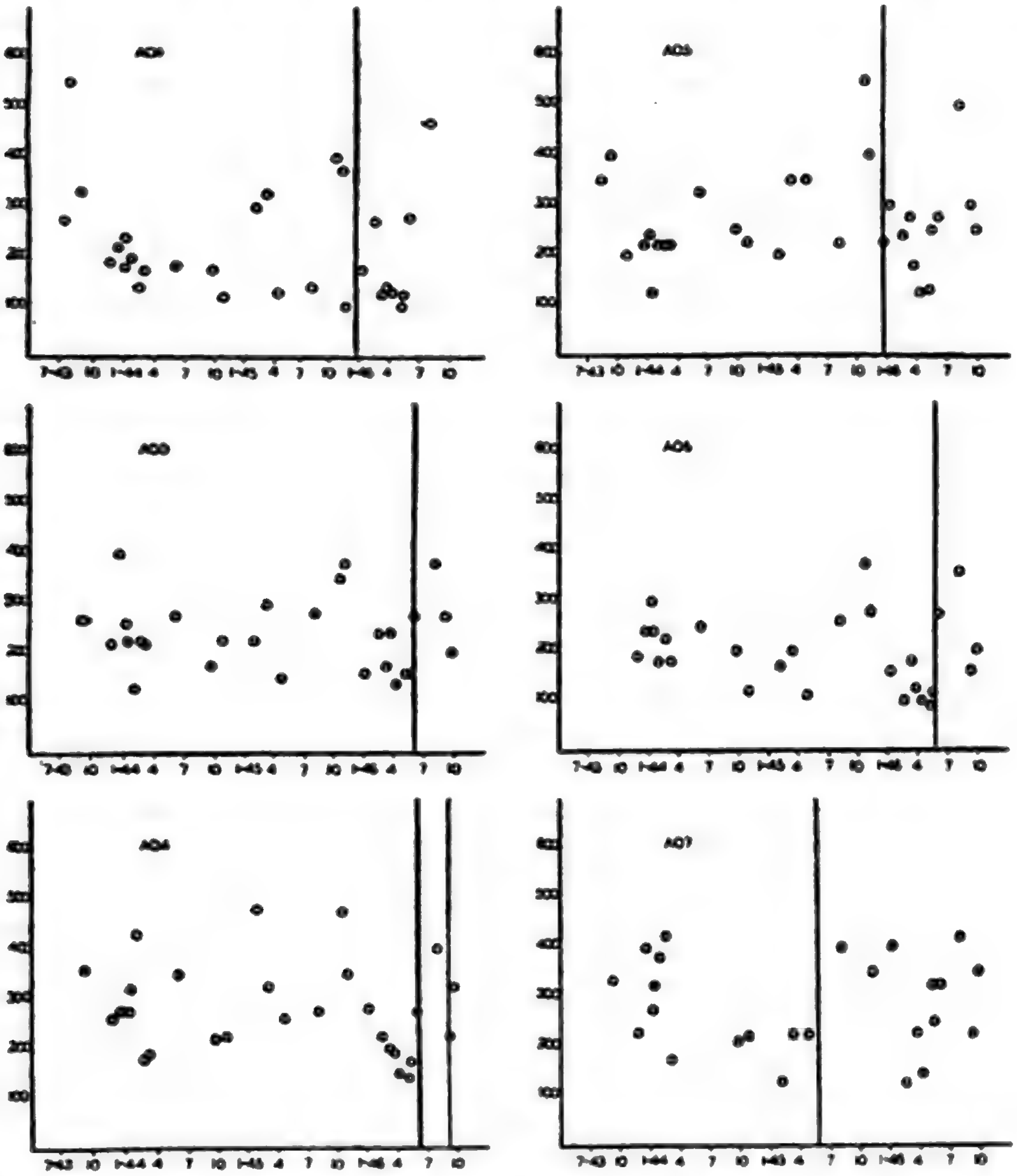


FIG. 53. Vibration sense—Left external malleolus—Threshold of vibration sense over the external malleolus in the AO group of patients, showing a marked decline in the number of frequencies perceived, especially in AO4 and AO7. The reversal period is indicated by the double line.

For comparison some patients chosen at random from the admission group of the hospital were used as controls. These patients suffered from various diseases of the nervous system, functional as well as organic. They were used as control subjects because they comprise a group similar to our experimental subjects. It is probable that the frequency range in the average population is higher and the decline not as rapid as shown in the charts. Figure 52 shows the values obtained in these patients for the various chronological age groups charted in 5-year intervals. As may be seen

74 different patients were tested and an average of 3 such tests performed on different days were charted. The threshold of frequency in these patients decreased with advancing age. The frequency ranged from 700 double vibrations per second in the younger group to about 250 double vibrations per second in the old age group when tested over the external malleolus. The sensitivity of the big toe to vibration was less than that of the external malleolus. It ranged from 500 to about 150 double vibrations per second.

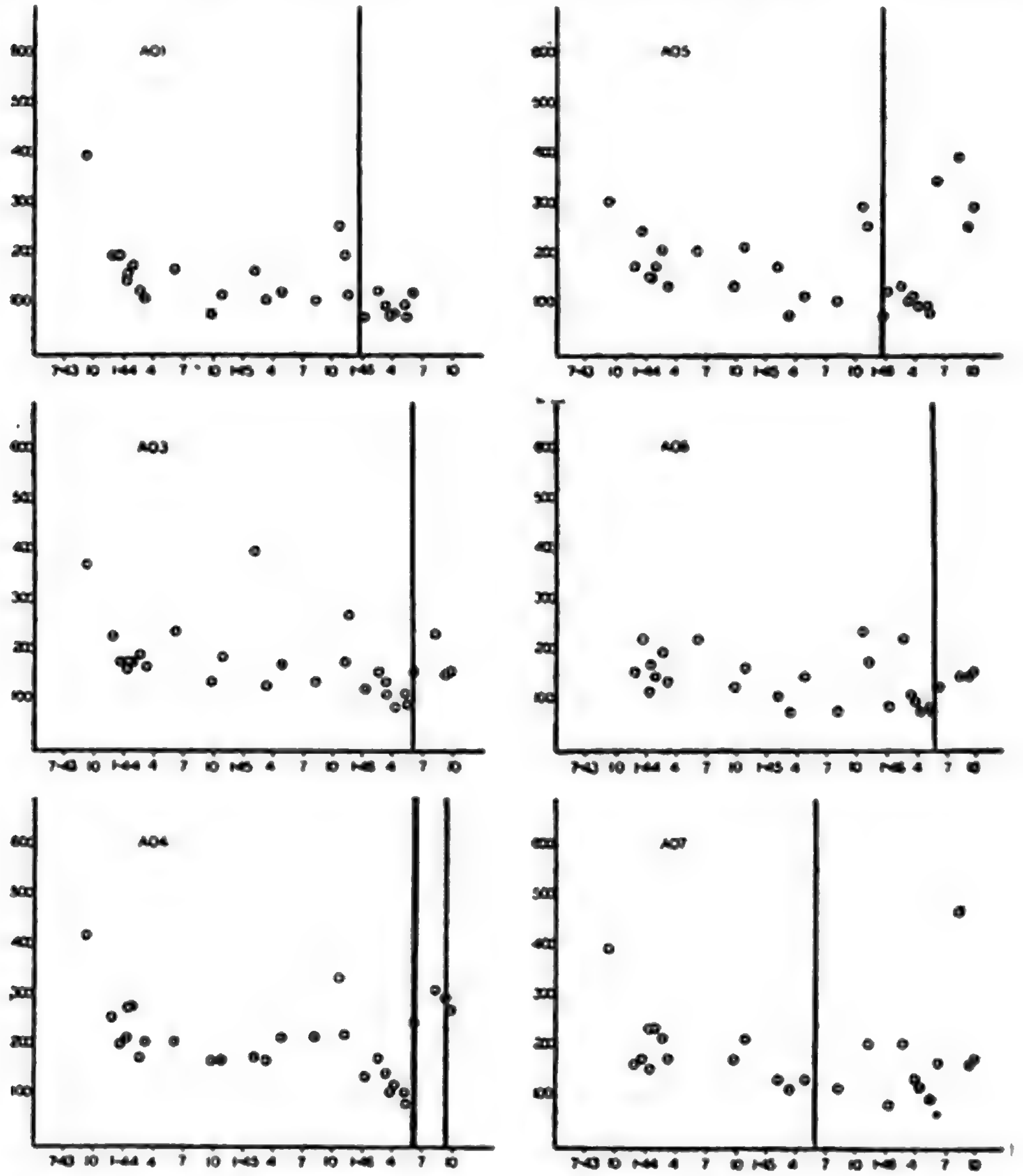


FIG. 54. Vibration sense—Left big toe—Same as Figure 53 but as tested on the left big toe.

Results.—The results of the study on vibration sense in the deficiency group are charted in the accompanying figures. These figures were drawn in such a manner that each point represents the actual value obtained on the tests from the beginning to the end of the study.

Individual charts of the patients show great fluctuations. Goodfellow reached similar conclusions. Figure 53 shows values obtained in the old persons of Group A for the vibration threshold of the left external malleolus. Except for one elderly patient in whom there seemed to be a definite tendency for diminished vibration sense at the end of the depletion period, the values were quite constant. The vibration threshold on the big toe (Figure 54), however, in the same group showed in almost all patients a tendency to a decrease at the end of the depletion period, with some increase following administration of yeast extract. A most significant finding was that at the end of the depletion period no high value was obtained in any of these patients.

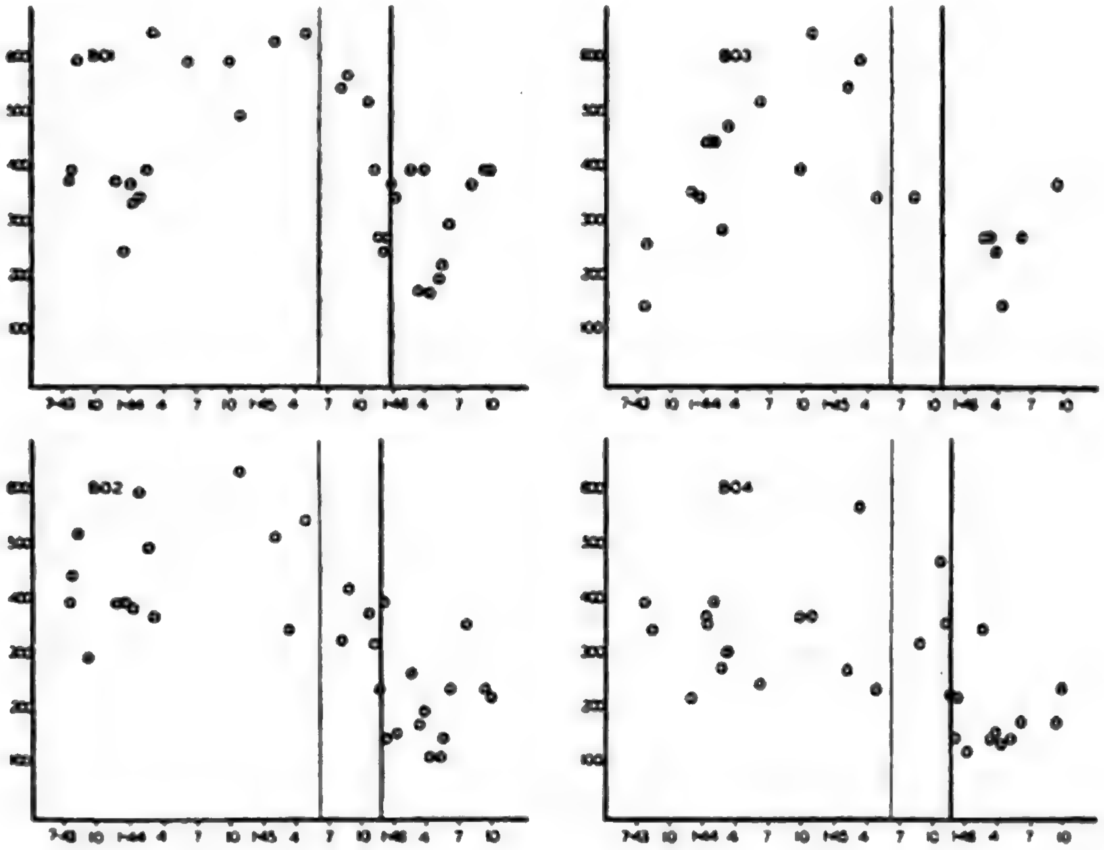


FIG. 55. Vibration sense—Left external malleolus in the BO group. Marked decline of the vibration sense perceived, especially in the patients BO1 and BO2. The end of the severe depletion period is indicated by the double vertical line.

In the B group (Figures 55 and 56) which comprised patients who were first given yeast extract and were later severely restricted in B vitamin complex it can be seen that during the first period of the examination marked fluctuations occurred in the values of the vibratory sense, but soon after June 1945 a definite drop occurred in all patients. The values decreased to 100 double vibrations per second and even lower. Figure 55 has the results obtained at the malleolus externus and Figure 56 has the values for the big toe.

Comment.—The results show that there is a tendency towards a decrease in the threshold of vibration sense in B vitamin complex deficiency. Such a relation of the vibration sense to vitamin intake has not been demonstrated before and the only paper relating to vibration sense in the aged has been that by Pearson in which the tuning fork was used and the time during which vibration could be felt was recorded. Pearson attributed his findings to arteriosclerotic changes in the blood vessels supplying the distal spinal cord. The question whether or not arteriosclerotic changes play an essential part in the diminished vibration sense is doubtful in the light of the writers' observations.

Some of the patients in this study had peripheral arteriosclerotic changes and some had hypertension, but there was no definite difference in the vibration sense threshold between these patients and those who were regarded as non-arteriosclerotic. The arteriosclerotic changes by themselves did not impair the vibration sense.

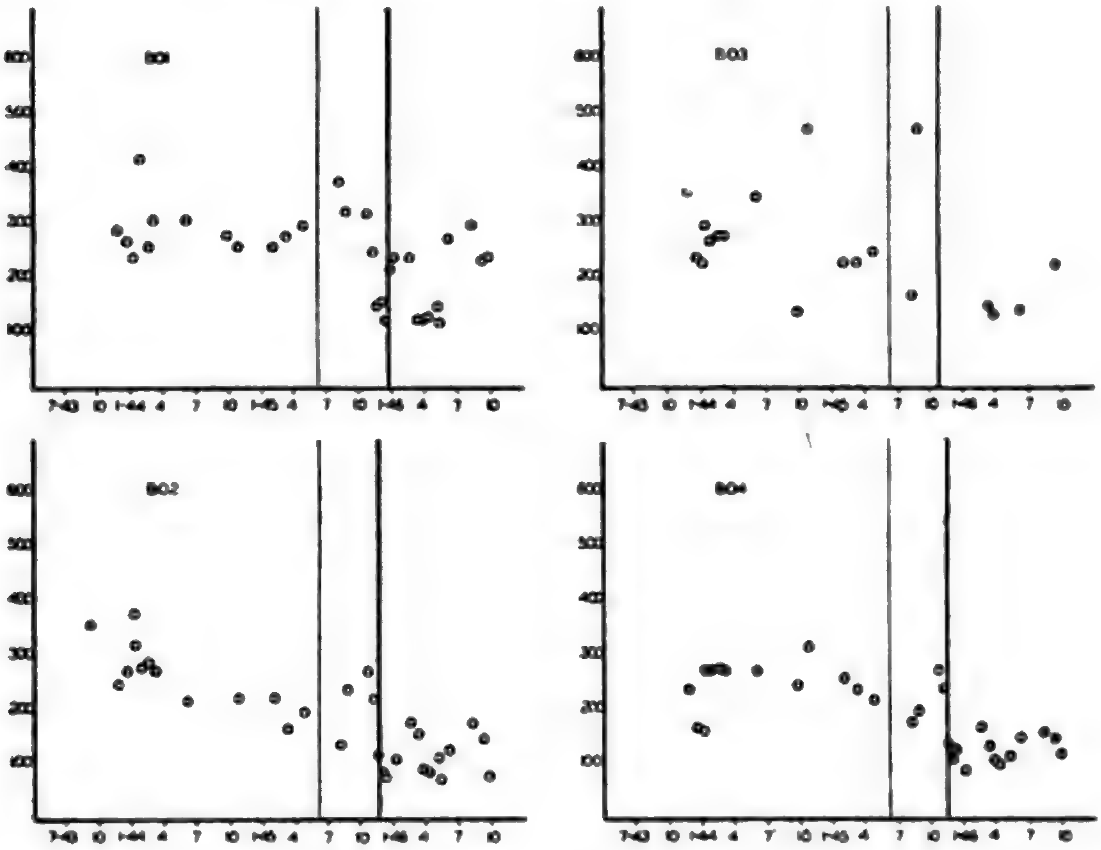


FIG. 56. Vibration sense—Same as Figure 55 but vibration tested on the left big toe.

Summary and Conclusions.—

1. The frequency threshold for the vibratory sense decreased with increasing age.

2. Vibrations were felt in higher range of frequency over the malleolus externus than on the soft part of the big toe.

3. A decrease in vibration sense seemed to be related to a B vitamin complex deficiency.

4. The patients in the older age group who had received vitamin supplements in the form of yeast had in general a higher threshold for vibration sense than those who were not supplemented.

5. Supplementation with yeast extract increased the threshold of vibration sense in patients who had been restricted in intake of B vitamin complex.

6. The threshold in vibration sense increased earlier at the malleolus externus than at the toe after supplementation with yeast extract.

7. Frequency variations of the vibratory sense when tested over a long period of time are a tool for predicting onset of neuropathy and, therefore, periodic tests of this sense are useful in assessing nutritional status.

REFERENCES

1. PEARSON, G. H. J.: The Effect of Age on Vibratory Sensitivity. Archives of Neurol. & Psychiat. *20:* 482–496, 1928.

2. YACORZYNSKI, G. K. AND BROWN, M.: Studies of Sensation of Vibration: Variability of Vibratory Threshold as Function of Amplitude and Frequency of Mechanical Vibration. J. Exp. Psychol. *28:* 509–516, 1941.

3. GOODFELLOW, L. D.: Artifacts in Investigation of Sensitivity to Vibration. J. Exp. Psychol. *35:* 425–431, 1945.

   GOODFELLOW, L. D.: The Sensitivity of Various Areas of the Body to Vibratory Stimuli. J. Gen'l Psychol. *11:* 435–440, 1934.

4. ARING, C. D. AND FROHRING, W. O.: Apparatus and Technique for Measurement of Vibratory Threshold and of Vibratory "Adaptation" Curve. J. Lab. Clin. Med. *28:* 204–207, 1942.

II. CHANGES OF TENDON REFLEX ACTIVITY DURING B VITAMIN COMPLEX DEPRIVATION

Orientation.—A study of the reflex activity in patients is one of the most important factors in routine neurological examinations. However, an evaluation of the results is difficult because of the vague descriptive terms used in recording the findings. Obviously if a reflex is completely absent such a statement has definite meaning, but changes of the reflexes usually are described as plus or minus or as slightly diminished, active, somewhat active, or quite active. The connotation of these terms may change, especially in long term studies. For instance, it is doubtful whether the examiner attached the same meaning to his terms after three years as he did in the beginning. A more definite evaluation of reflex activity by measuring the excursion of the motor component of the reflex would be helpful.

Method and Procedures.—The measurement can easily be made on the Achilles tendon reflex by testing the excursion of the foot after stimulating the Achilles tendon with a mechanical hammer of known weight falling through an arc at the same velocity. Such an instrument was built and measurements were taken on a horizontal board, the patient being in a kneeling position. The excursion of the foot was measured in mm.

Results.—The results of this study are recorded in Figures 57–60. At first glance they are quite variable. In some of the patients of the A group (moderate restriction), a definite increase in reflex activity can be noted. In the case of AO6 (Figure 57) the increase is about 6 mm. In the case of AO1 the reflex has more than doubled. However, in other patients like AO3 a marked decrease in the activity preceded by a period of increased reflex activity occurred during the restriction period. It is probable that in both instances, whether there was an increase or a decrease in reflex activity, some change in the nervous system had occurred causing a greater or a diminished irritability. The subject, AO3, had a marked increase in reflex activity prior to the extinction, indicating that a loss of reflex activity was preceded by an increase of irritability of the reflex arc. Such an evaluation of the findings in the A Group is supported by the study of Figure 58 in which four patients of the B group are charted, the group which first was supplemented and later on severely deprived of thiamine and riboflavin. In the case of BO5, the patient who always had an excellent Achilles reflex, a marked decrease in the Achilles reflex occurred December 1945. The reflex had not returned to normal in June 1946.

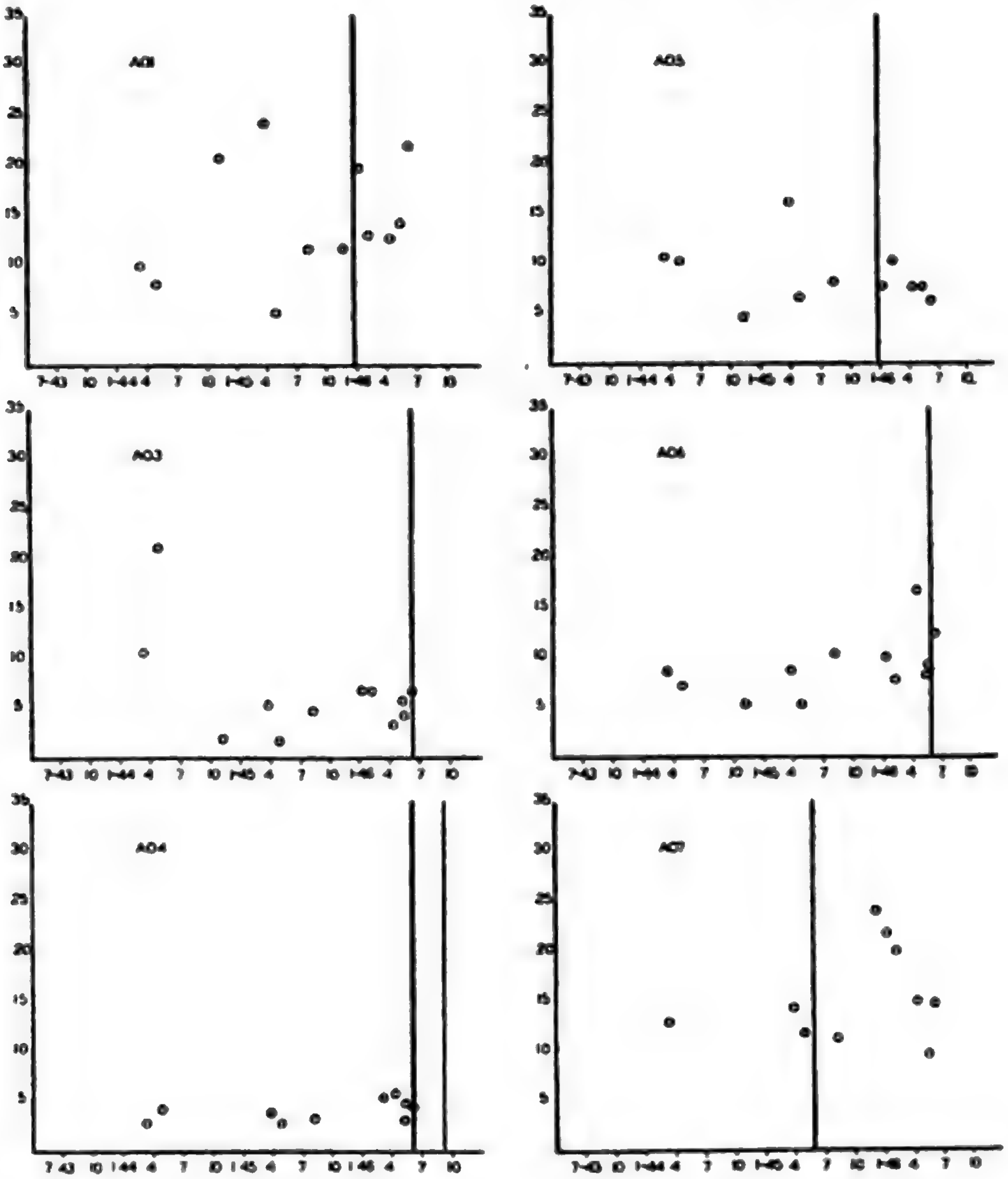


Fig. 57. Achilles Tendon Reflex—Right. AO Group—Tested with a mechanical hammer. Increase of the Achilles Tendon Reflex in AO1 and AO6. Marked decrease in the reflex tendency in AO3 during the time of depletion.

A similar decrease of reflex activity was recorded in the cases of BO4 and BO2. In the case of BO1 an increase in reflex activity was found and may have been the only objective sign of deficiency even after severe deprivation of B complex.

In the accompanying charts no complete absence of reflex is recorded. The reason is that slight displacement of the foot of about 2 mm. was caused by the impact of the hammer and had nothing to do with reflex activity.

The decrease in the reflex activity was more marked in cases of the younger group (Figures 59 and 60).

Comments.—The Achilles reflex activity was changed after a long period of marginal vitamin supply and after a short period of severe B vitamin complex restriction.

Not all patients responded in the same manner to the effect of the deficiency. In the A group most of the patients showed an increase in reflex activity after a long period of deprivation, but some patients showed severe decrease and even a complete loss of the Achilles reflex.

Since only passive cooperation was needed for carrying out the evaluation of the Achilles tendon reflex, this test was of definite value. The study of this reflex over an extended period of time gave a good indication of the presence or absence of any involvement of the peripheral nervous system.

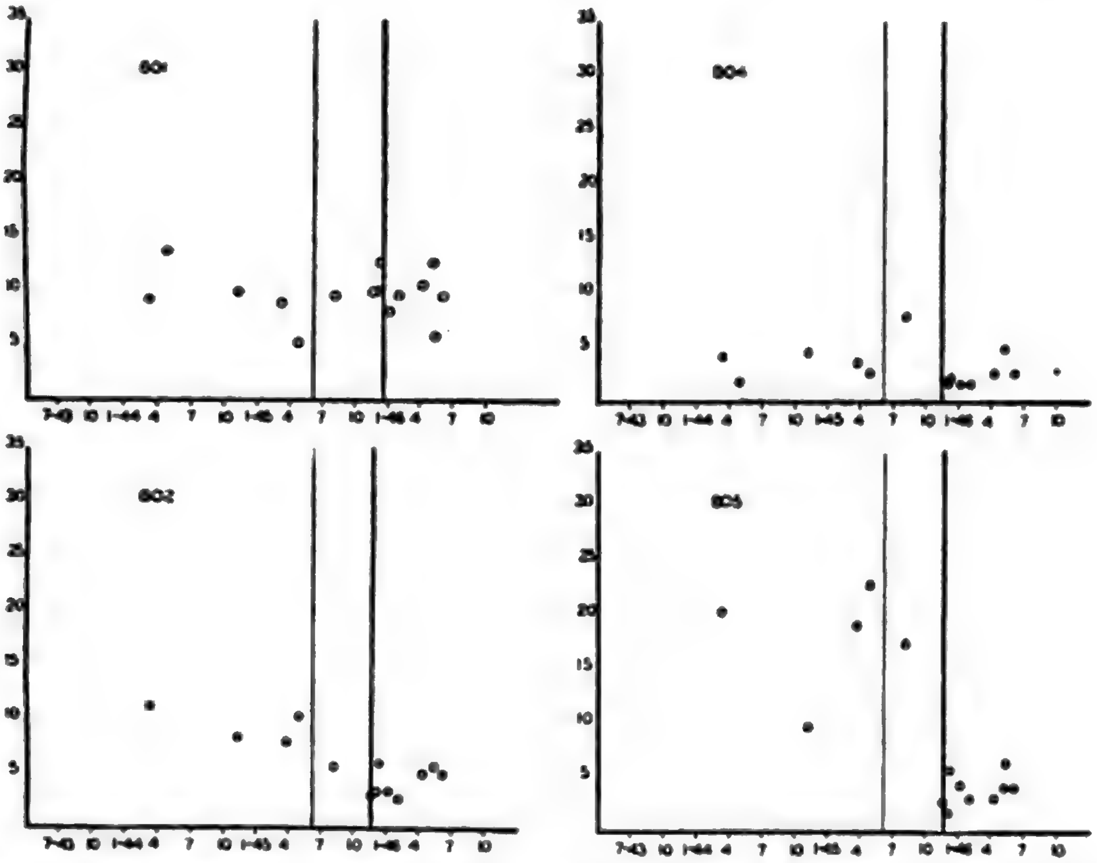


FIG. 58. Achilles Tendon Reflex—Right. BO Group—Tested with a mechanical hammer. Marked drop of the Achilles Tendon Reflex in patients, BO4, BO2, and BO5 during the time of severe restriction.

Summary and Conclusions:

1. The Achilles reflex was a sensitive sign of neurologic change and both increase and decrease in the reflex activity were observed in successive stages during B vitamin complex restriction.

2. A single testing of this reflex was not considered conclusive. However, after testing the reflex activity in the same patient over a period of time by the same method definite changes could be observed. Severe restriction of B vitamin complex led to loss of Achilles reflex after 5 months.

3. The cooperation of the patient was usually easily obtained for reflex studies. In this experiment evaluation of the Achilles reflex was of greater value than evalu-

ation of other sensory-motor pathways in which close attention and cooperation of the patient was needed.

III. STUDY OF ACUITY OF HEARING

A study on the acuity of hearing was thought to be important enough to be included in the experiment. A Maico audiometer was used for these tests and examinations were made by the same examiner at various intervals on those patients who were cooperative enough to give the required signal. In the ordinary range of frequencies the audiometer did not show any difference between the various groups of patients. Generally the younger group had a better hearing acuity than the older group. Variances occurred from patient to patient but no definite trend could

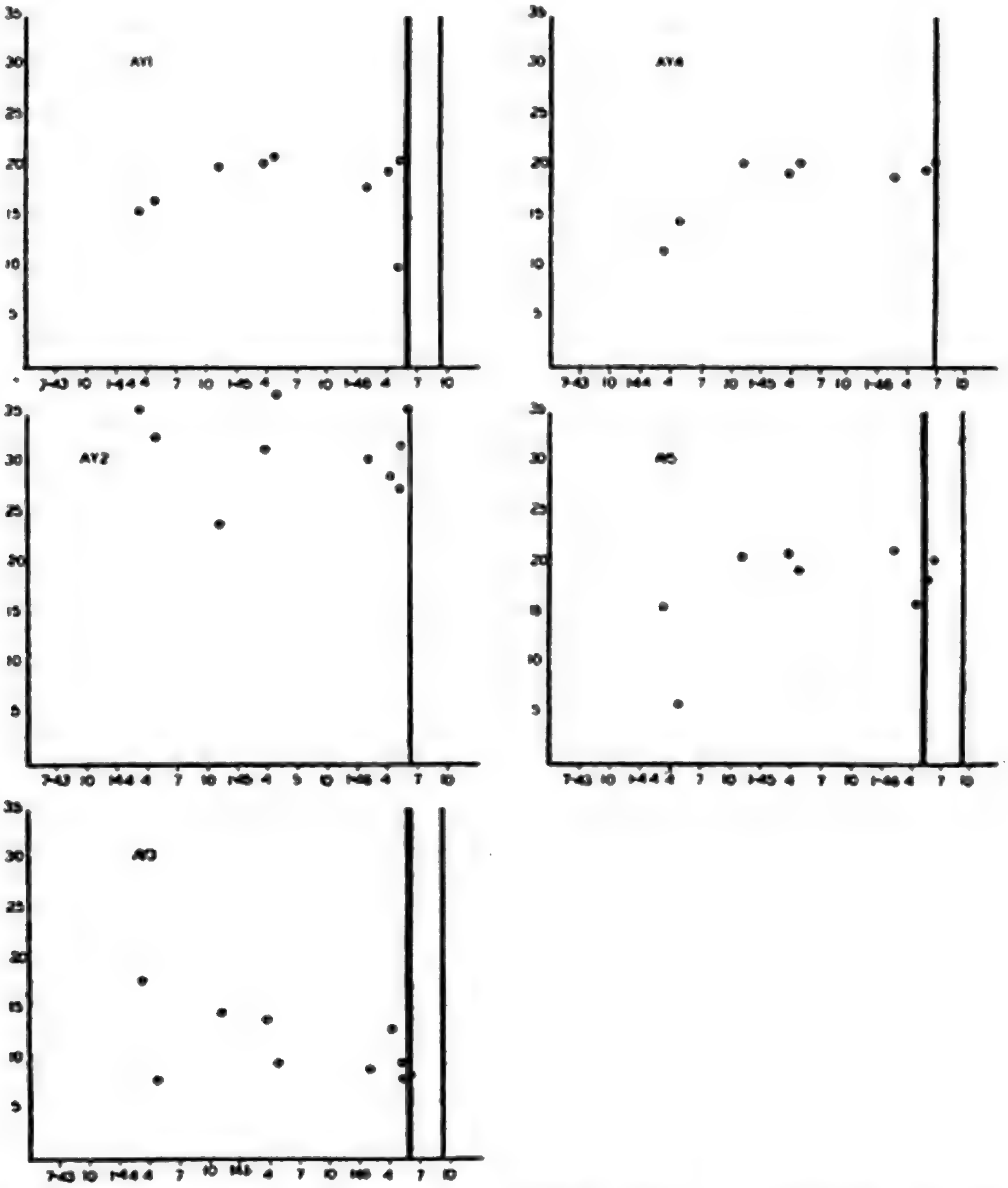


FIG. 59. Achilles Tendon Reflex—Right. AY Group—Tested with a mechanical hammer. No definite change in the reflex can be noted except in patient AY5 in which there is some increase in the reflex activity.

be noted. For a special study two frequency ranges, those of 2048 double vibrations and 4096 double vibrations per second, were selected. It was thought that if any changes could be expected such differences would occur in the higher tone range. Above 4096 double vibrations many of the patients did not hear at all, and it was, therefore, not feasible to use any higher frequency. No definite trends were noticed during the 3-year study with the audiometer in the A group and the hearing acuity remained about the same for these two frequencies.

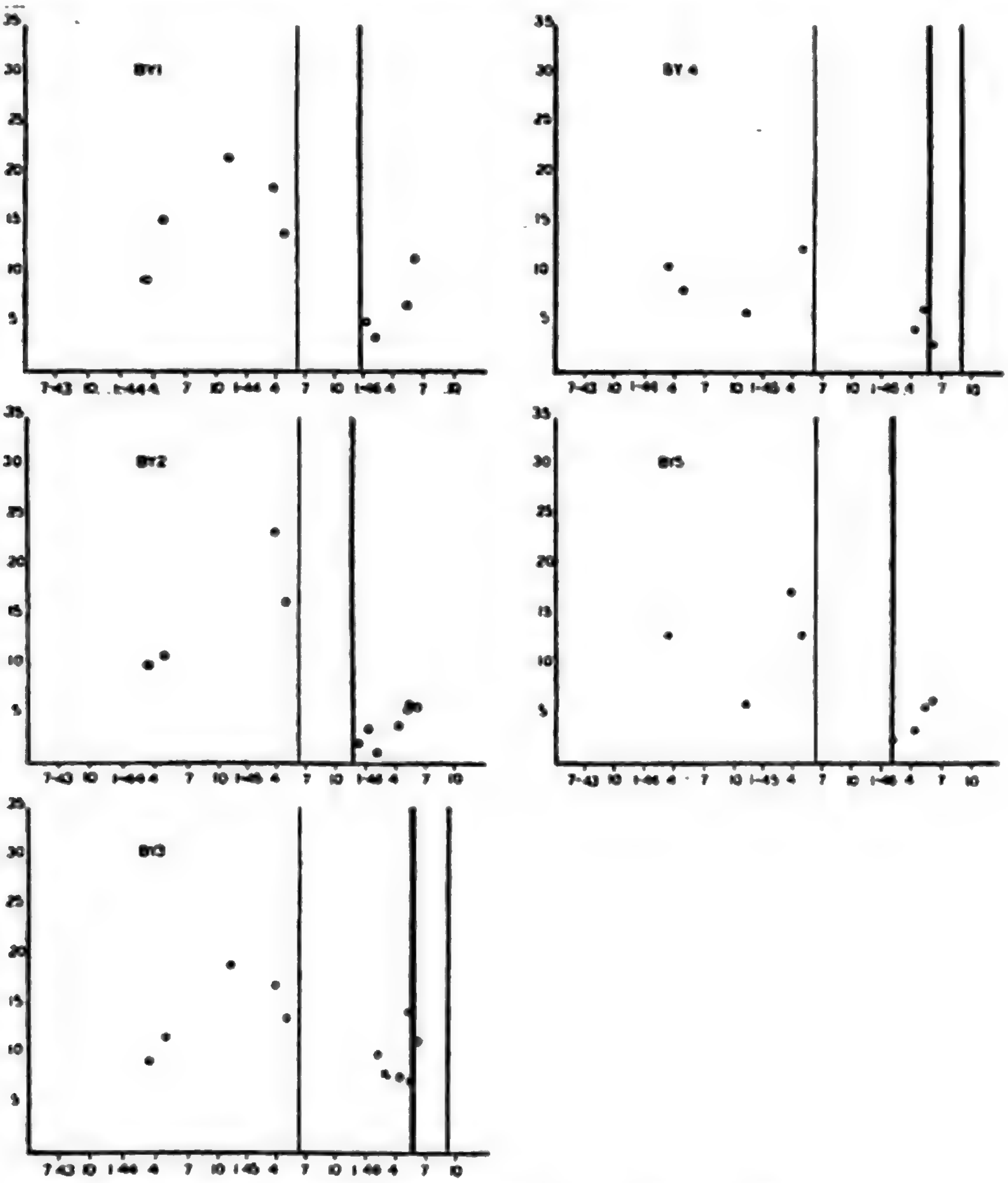


FIG. 60. Achilles Tendon Reflex—Right. BY Group—Tested with a mechanical hammer. Marked decrease in the reflex activity at the end of the severe depletion period.

The patients tested in the B group were limited to three because one patient could hear 4096 double vibrations only for a few weeks of the period of severe restriction of B vitamin complex.

When severe deficiency disease had been produced, as indicated by neuropathy, prostration, and severe biochemical change, a slight decrease in acuity as shown in the audiometer test for the higher frequencies was found. The significance of this decrease may be doubted because of the very small number of patients and since no similar decrease could be found in the A group. It may, however, be suggestive that after supplementation with yeast extract, all three patients showed an increase in the hearing acuity at 4096 double vibrations. The composite chart, including all patients, also indicated a definite increase of hearing acuity in this tone range. Such a change did not occur in lower frequencies.

In other contemplated depletion studies audiometer readings should by all means be included.

Conclusions:

1. No definite changes were noted in the audiometer in the lower frequencies during the time of marginal deficiency or of severe deficiency of thiamine and riboflavin.
2. A slight increase in decibels of hearing loss occurred in the range of 4096 in those patients who had a severe thiamine and riboflavin deficiency.
3. The number of patients tested satisfactorily in this examination is too small to draw any definite conclusions.

IV. STUDY OF CONTRACTION OF PUPILS IN RESPONSE TO LIGHT

One of the most common findings in the old age group is the rigidity of the pupillary contraction. It is also known that pupils in older persons do not contract over as wide a range as do those of younger people. While studying the effect of vitamin deficiency in ageing persons it was thought that patients with a progressing vitamin deficiency might show changes in the pupillary contraction time. If this could be substantiated such a procedure would be a rather objective measurement of the reflex activity.

Method.—In a dark room, two photo flood bulbs #2 were suddenly flashed into the eye of a patient at a distance of about three yards. The light source was used at the same time as an illuminator for a constant-speed motion camera and the pupillary contraction was photographed on a motion picture film. The number of frames used from the widest contraction to the smallest contraction of the pupil were counted, thus giving a measurement as to the speed of the pupillary contraction.

The study did not reveal any evidence of an effect of vitamin deficiency on pupillary contraction. The contraction time was almost constant in all our patients. The pupils contracted faster in younger persons than in older persons, but there were marked differences within the groups.

The conclusion of the study is that younger persons have a faster pupillary activity than older persons, but vitamin deficiency does not seem to have any influence on this difference.

The speed of contraction remained in general the same whether the patient was on a regimen of optimum vitamin intake or whether he was in a state of severe vitamin deficiency.

SECTION V

PSYCHOLOGICAL OBSERVATIONS

Phyllis Wittman, Ph.D.

Psychological study of the subjects in this research project was made to measure any change in mental efficiency levels, psychomotor skills, and attitude and behavior levels, with special attention to differences in the reactions of the two age groups, young and old.

Orientation.—It is well known that motor abilities, memory, perceptive ability, and combination and abstraction skills show a definite decline with age from the early twenties, of approximately 25 per cent for subjects 50 to 69 years of age and of 55 per cent for subjects 70 to 89 years of age. Imagination, comparison and judgment have a relatively late maturation and are without a pronounced age decline, possibly because speed is not a factor and memory is scarcely called upon (1). A study by Halstead (2) on senile patients indicated an inability in memory, inability to plan or reason, and inability to perform tests embodying difficult or lengthy instructions. According to Miles, (1) feeling and attitude factors are among those most severely affected by age. In addition to actual increase of handicaps with increasing age, the weight of feelings of inferiority and insecurity caused by decrease in physical strength and energy is by itself the greatest burden for the aged. In the study of Miles, younger adults tended to score higher on most of the measurements and older adults to score lower; however, not *all* of the high scores were made by the young nor all low scores by the old. Measures of dispersion were consistently large from decade to decade. In reaction time studies reported, 25 per cent of the people over 70 years of age were as quick as the average for the total group. In intelligence evaluations, even when speed was a factor, approximately a quarter of the older subjects equaled or exceeded the general adult score average. The observations cited emphasized that account must be taken of individual differences both for young and old subjects.

The psychological effects of vitamin deficiency were investigated in 1942 by O'Shea, Elsom and Higbe (3). They wrote:

> "although experiments in rats have shown impaired ability to learn a maze during deficiency of the B vitamins, in no instance have accurate psychological measurements of mental changes in such a deficiency been attempted in the adult human being."

Their subjects were eight middle aged women. The four experimental subjects were maintained under constant environmental conditions in a ward of the Philadelphia General Hospital. The four control subjects were equated with the experimental groups in age, general intelligence, and socio-economic level. They were employees of the hospital and consumed the hospital diet to which they had been accustomed for many years. Psychological tests of the subjects were made during the B vitamin complex deficiency period, at the end of a period of supplementation with thiamine, and again at the end of a period of supplementation with B vitamin complex. The only test that showed significant differences for the three periods was the Porteus Maze Scale. Foresight and judgment as measured by performance on maze tests were impaired when subjects were deficient in the B vitamins and were improved after therapy with thiamine or with B complex; general intelligence, reasoning ability, and speed of hand-muscle coordination (tapping) showed no measurable deterioration when the subjects were deficient in the B vitamins, and no improvement followed therapy with thiamine or vitamin B complex.

Another study of the effects of vitamin therapy which used psychological technics in the evaluation of results was that by Stephenson, Penton, and Korenchevsky (4). The published report did not give the psychological test findings but contained the statement that the objective results of the psychological tests corroborated clinical observations. "By treating aged people with vitamins, it was possible to prevent or improve, in some cases to a striking degree, certain of those senile features which could be considered as pathological, because they appeared prematurely or in an extreme degree (e.g. muscular, cardiovascular and mental deterioration) or which did not seem to be inevitable in normal physiological senility (e.g. dementia, insomnia, skin rashes, itching, constipation)."

The most recently published study on psychological findings on vitamin deficient human subjects is that from the University of Minnesota Physiological Hygiene Laboratory (5). Psychological evaluations of change in psychomotor skills, mental efficiency, and personality factors were made. Eight men served as subjects. In a period of partial restrictions there was no significant change in mental efficiency levels or any actual deterioration in any of the psychomotor measurements, which included two tests of strength, speed of small hand movements, gross body reaction time, manual speed and precise coordination (pattern tracing). In a period of acute deficiency there was evidence of marked deterioration in psychomotor functions although not in mental efficiency. Performance tended to return to a normal level after ten days of liberal supplementation of the experimental diet with synthetic thiamine. In the period of deficiency the scores on the Minnesota Multiphasic Scale revealed a marked increase in the strength of the hypochondriacal component.

Technical procedures of study.—The subjects for this study were classified into two groups. Both groups, one young, the other old, were composed of psychotic patients who were inmates of the Elgin State Hospital. Each age-group was then subdivided into two experimental groups and one reserve group. Group A received a diet moderately deficient in B vitamin complex throughout the experimental period; group B received the same diet but for group B it was supplemented with yeast extract. This supplementation continued for two years, then it was withdrawn and furthermore at that time (June 1945) the diet for the B groups was made markedly deficient in B vitamin complex. The subjects in the C group were considered reserves. They were not equated with the A and B groups and, at least psychologically, were so dissimilar that they could in no sense be regarded as controls.

The differentiating statistical data for the six groups at the beginning of the study are given (Table 18).

Both groups A and B contained some subjects who were entirely unsuitable for psychological evaluation. One in the young A group (AY4) was inaccessible for testing at any time because of extreme regressive factors, i.e., apathy, withdrawal, lack of contact with reality, and extreme unresponsiveness. Others (AY5), (BY3), (BY4), (AO6), (BO5) and (BO7) showed extremes of attitude, behavior, and efficiency factors which were related to fluctuations in psychotic ideation and behavior. They were in contact and fairly responsive for some testing periods and disturbed and actively hallucinated or extremely depressed and retarded at other times. Subject (BY1) was completely uncooperative for psychological tests throughout the entire experimental period because of paranoid delusional ideas about women and about being interviewed by them.

TABLE 18

STATISTICAL DATA FOR THE EXPERIMENTAL & RESERVE

	OLD SUBJECTS			YOUNG SUBJECTS		
Age (av.)	69 yrs.	64 yrs.	72 yrs.	31 yrs.	31 yrs.	27 yrs.
Education (av.)	8 yrs.	6 yrs.	5½ yrs.	10 yrs.	9 yrs.	6 yrs.
Hospitalized (av.)	8 yrs.	7 yrs.	23 yrs.	3½ yrs.	4 yrs.	2 yrs.
Mental Status (# of cases)						
Remission	4	3	0	0	0	0
Stationary	1	1	3	4	2	0
Deterioration	2	2	3	1	3	5
Diagnosis (# of cases)						
Chronic Alcoholism	2	0	0	0	0	0
Cerebral Arteriosclerosis	4	2	2	1	1	1
Paranoid	1	1	0	2	0	0
Affective	0	0	0	0	0	0
Schizophrenic	0	0	3	4	4	5
Test Cooperation						
Adequate Cooperation	4	3	1	1	0	0
Passive Cooperation	3	1	1	1	1	0
Variable Cooperation	0	0	2	2	1	1
Uncooperative Regression	0	1	1	1	2	5
Antagonistic & Uncooperative	0	1	0	0	1	0
Somatotype Average	3½42	343	2½34	235	234½	235½

Two of the old men in the A group, (AO2) and (AO7) had visual handicaps. Their performance on many of the tests was unreliable.

The aged subjects differed from the young subjects in body build. The former showed more mesomorphy (predominance of muscle and connective tissue), while the latter were primarily ectomorphic (characterized by linearity and fragility).

Three batteries of tests were employed (Table 19). The first was administered in May 1943 (before the beginning of the period of B complex vitamin restriction), again in May 1945 (after two years of restriction for the A groups but before the diet of the B groups was changed from a supplemented to a markedly deficient diet), and the third time in August 1946 (after a period of marked restriction of B vitamin complex for the B groups).

The second battery consisted of tests of psychomotor skills, developed by Dr. Robert Seashore and associates at Northwestern University. They were administered by Mr. Wilson Young, a graduate student at Northwestern University, during the periods indicated above, that is before, during, and after restriction of B complex.

The third battery included tests of mental efficiency (relatively unaffected by practice) and rating scales of attitude and behavior. This battery was administered each month throughout the experimental periods.

TABLE 19

BATTERY I MENTAL EFFICIENCY LEVELS	BATTERY II PSYCHOMOTOR SKILLS	BATTERY III EFFICIENCY AND ATTITUDE
Illinois Initial	Pursuit Plane	Tapping Test
General Efficiency	Photostatic Aiming Device	Dash Opposites
Concrete Performance	Ataxiometer	Letter same
Vocabulary Level	Visual Reaction Time	Rote Memory
Test Reaction		Digits Forward
		Digits Reversed
Wechsler Bellevue		Rate of Manipulation
General Intelligence		Hand Dexterity
Verbal Intelligence		Finger Dexterity
Concrete Intelligence		
Deterioration Quotient		*Attitude and Behavior*
		Elgin Test Reaction
Abstract Thinking Test		Elgin Attitude List
Weigl (Elgin Revision)		Illinois Behavior
Because Sentences		
Koh's Blocks		
Sorting Test		

It was thought that the results of the tests for Battery I could be handled statistically only by an analysis of covariance. Dr. Robert L. French, Professor of Psychological Statistics at Northwestern University, undertook such an analysis.

Only the results for the first two test-periods were analyzed, (i.e. the period of preliminary observation and following the period of moderate restriction of B vitamin complex for A groups and just before the diet of the B groups was changed from the supplemented to the markedly deficient diet).

For each test the plan was to determine whether the difference in diet during this period of 24 months caused a terminal difference in performance of the two dietary groups; and/or whether it caused a different effect upon the several age groups.

The technic of analysis of covariance performed essentially two functions: (a) it removed from the final scores the effects of differences in initial status, and (b) it provided an analysis of variance of the adjusted scores into four independent parts: (1) variance due to differences between dietary groups; (2) differences between age groups; (3) interaction between diet and age (i.e. differential effects of dietary differences upon different age groups); and (4) differences between individuals after the preceding three effects were eliminated. The data provided by Elgin Test Reaction Scale (Table 20) shows that the F ratio for diet (i.e. variance between dietary groups, divided by variance within groups) is 11.29. The value of F required for significance at the 1 per cent level of confidence is 9.07. In other words, if there were *no* effects of diet upon this performance, an F of the size observed would be obtained (by chance) in less than 1 per cent of a series of comparable samples. The inference is that the difference in diet had an effect on this performance (test reaction) which is highly significant from a statistical standpoint.

The F ratio was statistically significant in only four tests. On only one, the Elgin Test Reaction, was diet a significant factor in itself. In all four, the "Diet X Age" interaction was significant, indicating a differential effect of diet upon different age groups.

The Elgin Test Reaction Scale is a rating scale which evaluates those attitudinal components that strongly affect the reliability of psychological test findings, such as attention, interest, willingness, social confidence, effort, motivation, volubility and relevancy of speech, emotional reactions, self confidence, decisiveness, and autocriticism. The findings suggest that the borderline deficient diet affected for the worse reactions in the test situation. This is in harmony with the University of Minnesota report of changes in attitude and temperament factors without definite change in mental efficiency. It also agrees with the subjective complaints of the subjects and with the clinical observation that the deficient subjects were lethargic and inattentive and had labile emotional reactions.

TABLE 20

SIGNIFICANT RESULTS WITH ANALYSIS OF COVARIANCE

"F" Ratio

TEST NAME	DIET	"DIET X AGE"	5% LEVEL	1% LEVEL
I.I. Performance	3.81	5.17	4.75	9.33
W.B. Performance	1.01	11.97	4.75	9.33
Elgin Test Reaction	11.29	10.92	4.67	9.07
Substitution Test	2.81	10.71	4.67	9.07

The other three tests of significance for the interaction of diet and age factors all have certain things in common. They are performance rather than verbal tests; that is, they require movement and manipulation rather than speech on the part of the patient. They are timed tests and speed of response enters as a factor. They are all tests of a type in which older subjects perform less effectively than younger adults. Moreover, they are tests in which weakness and fatigue, lethargy, and indifference markedly affect the results.

The author is aware of the necessity of caution in the interpretation of these results. Proper application of the analysis of covariance rests upon a number of assumptions of which some are violated in the present analysis. For example, subjects were not drawn at random from the population and they were not assigned at random to the two dietary groups. Other complications arise, for there were possible diagnostic differences between the age groups, and there was possible (and differential) deterioration of the subjects during the experimental period independently of any other variables. These violations of assumptions and the complications make it improbable that other and more involved assumptions underlying application of this technic can be satisfied. When these several factors were considered it seemed impossible to make further statements based on statistical analysis of the data for Battery I.

An analysis of the data of the tests of psychomotor skills (Battery II) suggested that the condition of nutritional deficiency was statistically significant in lowering performance efficiency on tests of psychomotor skill. It further indicated that quickness of response was adversely affected in the young restricted group and hand-arm steadiness was reduced in the vitamin deficient aged. The variables to be considered were: progressive deterioration of the old subjects due to natural organic change which might be incorrectly interpreted as due to the experimental variable; cyclic fluctuations in the mental state of psychotic patients; changes in voltage of electric current; and calibration of instruments used.

TABLE 21

TRENDS ON MONTHLY TESTS, BATTERY III

(May '43 to June '45)

OLD SUBJECTS	MENTAL EFFICIENCY	ATTITUDE BEHAVIOR	YOUNG SUBJECTS	MENTAL EFFICIENCY	ATTITUDE BEHAVIOR
AO1	0	0	AY1	0	0
AO2	Incomplete Data		AY2	0	−
AO3	0	±	AY3	0	±
AO4	0	∓	AY4	N.C.	0
AO5	∓	0	AY5	±	±
AO6	Incomplete Data				
AO7	−	∓			
BO1	0	0	BY1	N.C.	0
BO2	0	±	BY2	−	−
BO3	−	0	BY3	±	∓
BO4	0	0	BY4	±	∓
BO5	±	±	BY5	0	±
BO6	−	−			
BO7	Incomplete Data				

+, improved;
±, extreme variability from one testing period to another;
0, unchanged;
∓, extreme variability, worse more often than better, from one period to next;
−, poorer, and
N.C., not cooperative.

Certain of the old subjects with occupational experience in areas similar to those measured had test scores considerably superior to the mean of the young group. This suggested influence of occupational conditioning on certain psychomotor functions.

The data of Battery III collected each month on the patients in this study showed extreme variations for the individual patients in each group. Tests were made each month to determine the trend for each individual patient. For the *first* experimental period from May 1943, to June 1945, these trends are shown (Table 21).

Attitude and behavior factors showed a downward trend for some of the subjects in both the old and young deficient groups. However, some of the subjects in the B (supplemented) groups also showed a worsening of attitude and behavior, particularly for the young group. This may be associated with the ennui and disinterest resulting from the rigidly controlled daily routine and a repeated testing program every month throughout a two-year period.

TABLE 22

TRENDS ON MONTHLY TESTS, BATTERY III

(Up to time of resupplementation)

OLD SUBJECTS	MENTAL EFFICIENCY	ATTITUDE AND BEHAVIOR	YOUNG SUBJECTS	MENTAL EFFICIENCY	ATTITUDE AND BEHAVIOR
AO1	0	∓	AY1	0	∓
AO2	Expired 12–45		AY2	∓	∓
AO3	−	∓	AY3	0	±
AO4	∓	∓	AY4	N.C.	0
AO5	±	0	AY5	0	∓
AO6	−	∓			
AO7	Expired				
BO1	0	0	BY1	N.C.	∓
BO2	−	∓	BY2	−	∓
BO3	−	−	BY3	0	0
BO4	−	−	BY4	0	∓
BO5	−	∓	BY5	∓	−
BO6	Expired 9–45				
BO7	Expired 7–46				

+, improved;
±, extreme variability from one testing period to another;
0, relatively unchanged;
∓, extreme variability, poor scores particularly from one period to next;
−, worse; and
N.C., not cooperative.

The only subjects showing a marked decrease in mental efficiency level during this period were old men, and since not all were in the borderline deficient group it would appear that this decrease in mental efficiency was associated with the factor of age rather than with the factor of diet. Trends for the second experimental period (commencing June 1945 when the diet of the B groups was changed from a supplemented to a markedly deficient diet, to the time when the individual patient was restarted on yeast supplementation because of clinical evidence of deficiency) are shown (Table 22).

Evaluations were made of trends for the second experimental period, June 1945, up to time of resupplementation for the B groups and for the period of borderline deficiency for the A groups. Since there was a trend toward impairment in attitude and behavior for the A groups, either there was cumulative effect of boredom and dissatisfaction or cumulative effect of a borderline deficient diet, continued for an extended period of time, which reacted negatively on attitude and behavior factors.

There were definitely lower trends for attitude and test reaction factors among the B groups during the second experimental period when these patients were on a markedly deficient diet. Mental efficiency was lowered for one of the young and four of the old patients in the B group. However, two of the young subjects and one of the old subjects did not show a trend toward lowered mental efficiency even up to the time that clinical signs of deficiency became so advanced that it was necessary for clinical reasons to terminate the dietary restriction. Also there were large individual differences on psychological tests in response to marked vitamin deficiency. Two young subjects, BY3 and BY4, did not show a worsening effect in either mental efficiency or attitude and behavior factors throughout the period of marked restriction. Also, the factors of individual differences were of such importance (e.g. BO1, who although aged and on a markedly deficient diet, functioned at a level far above that of younger subjects with an adequate diet), that it is impossible either to prove or to disprove the thesis advanced by Stephenson and associates (4).

TABLE 23

TRENDS ON MONTHLY TESTS, BATTERY III

(Following Resupplementation)

OLD SUBJECTS	RESUPPLEMENT DATE	MENTAL EFF.	ATTITUDE BEHAVIOR	YOUNG SUBJECTS	RESUPPLEMENT DATA	MENTAL EFF.	ATTITUDE BEHAVIOR
AO1	12–45	–	–	AY1	9–46	0	+
AO2	—	No data		AY2	6–46	0	±
AO3	6–46	±	0	AY3	9–46	No data	
AO4	9–46	No data		AY4	6–46	N.C.	0
AO5	12–45	0	0	AY5	6–46	0	±
AO6	6–46	0	+				
AO7	5–45	–	∓				
BO1	12–45	0	0	BY1	12–45	N.C.	∓
BO2	11–45	±	+	BY2	11–45	∓	∓
BO3	10–45	–	+	BY3	9–46	No data	
BO4	12–45	–	+	BY4	9–46	No data	
BO5	11–45	±	0	BY5	2–46	0	±

The trend from the time of resupplementation on the battery of tests and scales administered monthly is shown (Table 23). With moderate restriction of B vitamin complex (A groups) there was marked improvement following resupplementation for one old and one young subject in attitude and behavior factors but without corresponding improvement in mental efficiency. Three of the old subjects who had been severely restricted (B group) showed marked improvement in attitude factors following supplementation but only one of these three showed any change in mental efficiency and the other two continued to show a deteriorative trend. This suggests that in a long-continued study such as this, so-called "normal deterioration" among the old subjects must be considered in evaluating effects of restriction of B vitamin complex. There is also the possibility that the recuperative powers among old subjects, although they vary greatly, are not as marked as for younger subjects.

In an effort to coordinate the psychological findings on mental efficiency and attitude and behavior factors with the psychiatrist's ratings of mental status following both modified and marked restriction of B vitamin complex, scatter diagrams were constructed.

There is little agreement between trends in mental efficiency and psychiatrist's evaluation of mental status following B vitamin complex restriction. Much better agreement was found between data trends on rating scales of attitude and behavior and psychiatrist's evaluation of mental status. This is what we would expect to find since the psychiatrist's evaluations were based primarily on these same attitude and behavior factors. The lack of agreement with mental efficiency would also be expected by any of those familiar with the individual patients' reactions to the testing situation. One of the patients, AY1, showed this difference between test performance and behavior to an extreme degree. Although slowed up and increasingly apathetic and withdrawn, he was easily stimulated by the testing environment and in general maintained his mental efficiency level throughout the deficiency period. Although actively hallucinating during some of the testing situations and showing little, if any, overt interest in the tests, he was nevertheless able to keep up his relatively high standing throughout the deficiency period. Apparently the monthly testing intervals were a break in the routine for this patient as well as for several others and they responded to this by making an effort to do well.

TABLE 24

SCATTER DIAGRAMS SHOWING CORRELATION BETWEEN PSYCHOLOGICAL FINDINGS AND PSYCHIATRIST'S RATING OF PATIENTS ON RESTRICTION OF B VITAMIN COMPLEX

PSYCHOLOGICAL DATA ON MENTAL EFFICIENCY	PSYCHIATRIST'S EVALUATION OF MENTAL STATUS				
	−4	−3	−2	−1	−0
±					
0	1		2	2	1
∓				3	
−		2	2	1	2
N.C.			1	1	1
ATTITUDE AND BEHAVIOR	MENTAL STATUS				
±				2	3
0			1	3	1
∓			4	5	
−	1	1			

Comment and Conclusions.—Since the psychologists administering and scoring the test technics did not have any knowledge about which group, A or B, the individual patients were in, the results are completely unbiased by any subjective correlations.

The subjects for this project were selected with the requirements for various biochemical and physiological tests in mind and they were not cooperative for the entire battery of psychological tests. Individual differences for the subjects in ability as well as in attitude and behavior were so varied and related to the different types of psychosis, that neither the age groups nor the experimental sub-groups could be equated. The best that could be done in evaluating psychological factors was to consider each subject as his own control by comparing his pre-experimental levels of behavior and efficiency with his subsequent status. In spite of these several inherent difficulties, psychological tests were made (a) for evaluation of psychological variables within the limits allowed, (b) for the orientation of the experimenters and others who were interested in this study and (c) for the information of those who may undertake similar research. Bearing in mind the limitations as to the reliability of the responses, conclusions are as follows:

1. In general, attitude and behavior declined for both old and young subjects during moderate restriction of B vitamin complex. However, there was a similar trend among subjects who received supplements of yeast extract during the first two years of the study. This trend suggests that factors of boredom and ennui associated with long-continued regimentation necessary for the experiment were not excluded as factors in decreasing adequacy of attitude and behavior levels.

2. The old subjects as a group were more affected than the younger subjects by the moderately restricted diet. This was true not only for test reactions but also for performance tests stressing speed and manual manipulation as well as comprehension. There is another complication, that of age, which enters here however. The decrease in motivation and interest and the increase in subjective complaints, as well as the decrease in ability on performance and speed tests, may be at least partially explained by the continuing deteriorative process for the old subjects throughout the three-year period of experimentation.

3. A statistically significant drop in performance involving psychomotor skills was noted for the moderately restricted subjects. This agrees with the finding of decrease in ability on performance tests (see Table 19) when the diet was moderately deficient in B vitamin complex, when compared with groups on yeast supplementation.

4. Apparently, mental efficiency was not impaired to a significant degree by a diet moderately deficient in B vitamin complex, judging from the scores for the young group. Two of the old patients did show a marked trend toward decreased efficiency following three years of restricted diet (see Table 22) but again this can be considered the expected deterioration associated with ageing for these old subjects. Also although mental efficiency of some old subjects on restricted B vitamin complex did deteriorate during the course of the study (1943–1946) this deterioration occurred also for some of the old subjects in the B group when they had received supplements of yeast extract during the first two years of the study (1943–1945) (Table 21). Apparently the process of ageing rather than dietary restriction was the cause of this deterioration.

5. Severe restriction of B vitamin complex was associated with a marked drop in attitude and behavior factors and, for the majority of old subjects, in mental efficiency as well. Since more of the old subjects on severe B vitamin complex restriction for one year or less showed this trend than did the old subjects on borderline restriction for a three-year period, this can probably be attributed, in part at least, to the severe restriction. Another point supporting this conclusion is the fact that one of the young subjects on severe B vitamin complex restriction also showed a decrease in mental efficiency and this decrease could not be explained on the basis of deterioration with age.

6. There were marked individual differences in psychological reactions of the subjects with both borderline and severe B vitamin complex deficiency. For each group, both old and young, both borderline and severely restricted in B vitamin complex, there were individual differences within the group. Subject BO1 illustrates this difference strikingly. Although in his seventies and one of the subjects on severe restriction he did not show any deterioration either in attitude and behavior or in mental efficiency levels as a result of this restriction, while all of the other old men in this group did show such deterioration, at least in mental efficiency.

7. The psychological findings were not clear enough either to prove or to disprove the thesis of Stephenson, Penton, and Korenchevsky that it is possible to prevent or improve certain senile features by treating aged people with B vitamin complex. The only conclusion would be that aged subjects showed as marked individual differences to B vitamin complex restrictions as young subjects. Possibly the recuperative powers of the aged following restriction may not be as great as those of the younger subjects (see Table 23) but definite conclusions can not be drawn because the "normal" deteriorative process of ageing may mask such recuperation in the area of mental efficiency for the old subjects.

REFERENCES

1. MILES, WALTER, R.: Age and Human Ability. Psychol. Rev. *40:* 99–123, 1933.
2. HALSTEAD, HENRY: A psychometric study of senility. J. Ment. Sci. *89:* 363–373, 1943.
HALSTEAD, HENRY: Mental tests in senile dementia. J. Ment. Sci. *90:* 720–26, 1944.
3. O'SHEA, H. E., ELSOM, K. O. AND HIGBE, R. V.: Studies of the B vitamin in the human subject. Am. J. Med. Sci. *203:* 388–97, 1942.
4. STEPHENSON, W., PENTON, C. AND KORENCHEVSKY, V.: Some effects of vitamin B and C on senile patients. Brit. Med. J. 839–44, 1941. (2).
5. GUETZKOW, H. AND BROZEK, J.: Intellectual functions with restricted intakes of B complex vitamins. Am. J. Psychol. *59:* 358–81, 1946.

SUMMARY AND GENERAL CONCLUSIONS

Ray D. Williams, M.D., E. S. Guzman Barron, M.D., Conrad A. Elvehjem, Ph.D. and Max K. Horwitt, Ph.D.

The study here reported is unique with respect to the length of time that human subjects have received weighed diets of predetermined composition. A group of twelve mental patients was continuously maintained for a period of three years on a diet of which the content of thiamine was approximately 400 and that of riboflavin close to 800 micrograms. Another group of twelve individuals, serving first for negative and later for positive control, received the same diet for two years, supplemented with yeast extract to supply a liberal allowance of B complex vitamins. After this the subjects of this group received a diet of which the content of thiamine was only 200 micrograms. A third group of subjects received the general diet of the hospital. The project was designed to give further information on minimal requirements for B complex vitamins with reference to the relative needs of older versus younger men, as well as on the influence of low and high intakes of these vitamins on the symptoms of the mentally infirm.

Thirty-six men were selected from the patient population of the Elgin State Hospital to be subjects of the study. They were housed in an isolated building (Wing Cottage) and maintained there continuously under rigid supervision. The patients volunteered to serve as subjects and the consent of the guardian or family was given in each instance.

The subjects were divided into groups A, B, and C. Groups A and B each contained five younger and seven older men. The diet for these two groups was planned to be adequate with respect to all of the essential nutrients except thiamine and riboflavin. The allowances of thiamine and riboflavin, 400 and 800 micrograms respectively, represented allowances which earlier investigation on animals and human subjects suggested would be only slightly less than minimal requirements. The diet for the subjects of group B was supplemented daily with yeast extract, which increased the provision of thiamine and riboflavin by not less than 3.6 mg. of thiamine and 2.3 mg. of riboflavin. Group C contained twelve subjects who ate the general hospital diet.

After two years of the liberal provision of B complex vitamins, the diet of the subjects of group B was changed. It became more rigidly restricted with respect to thiamine than the diet of the subjects of group A. Thereafter the subjects of group B obtained only 200 mcg. of thiamine and no yeast extract.

BIOCHEMICAL OBSERVATIONS

Proceeding on the assumption that chemopathological changes take place in the tissues of the thiamine-deficient subject because of the lack of cocarboxylase, and that such changes would be among the earliest effects of thiamine deficiency, considerable effort was expended in examining the carbohydrate metabolism. The possibility that changes, such as the previously reported alterations in lactic and pyruvic acid levels of blood plasma, might provide a method for diagnosing early or mild thiamine deficiency was thoroughly investigated. The data obtained support the conclusion that the basal blood levels of lactic and pyruvic acid are of little, if any, value for this purpose. It would seem that in less severe states of thiamine deficiency the organism at rest can maintain the normal equilibrium levels of lactic and pyruvic acids, that only later, after pronounced signs of clinical pathology become apparent, are the basal levels of lactic and pyruvic acids elevated, and that they then are elevated only in some cases. Since basal blood levels proved to be of little value for estimating mild degrees of thiamine deficiency, a metabolic load such as glucose administration, or exercise, or a combination of the two loads was imposed in order to strain the cellular metabolism to a point at which the additional work which had to be done by the weakened organism would manifest itself in the accumulation of lactic and pyruvic acids. The determinations of the levels of lactic and pyruvic acids after the administration of glucose to individuals with variable glucose tolerance curves proved to be of value, but this was true only when the levels of these acids were correlated with the amount of glucose present in the blood at the time. A large number of such determinations demonstrated a relationship between the glucose and the lactic acid and pyruvic acid concentrations of the blood.

Search for a metabolic load best suited to uncover mild and cryptic deficiency of B vitamins revealed that mild exercise imposed 60 minutes after giving glucose orally was satisfactory. The levels of lactic and pyruvic acid of blood drawn 5 minutes after completion of the exercise appeared to be of diagnostic value when adjusted for the level of the glucose in the blood.

The omission of either the glucose load or the exercise load lessens the sensitivity of the test. By considering the normal relationships of glucose, lactic acid, and pyruvic acid in the blood, which obtain as a result of the combined glucose-exercise test, one can use the following formula to calculate an index of carbohydrate metabolism:

$$\mathrm{CI} = \frac{\left(\mathrm{L} - \frac{\mathrm{G}}{10}\right) + \left(15\mathrm{P} - \frac{\mathrm{G}}{10}\right)}{2}$$

The validity of this index has been established. All subjects in the B groups had a CI of less than 15 during the first two years of the experiment when they were receiving a yeast extract supplement and served as controls for the A groups. During this time the subjects of the A groups gave variable results, at times above, at other times below 15. Initial determinations were not obtained because the index was not developed until nine months after the beginning of the study; however, within two to five months after the B groups had been placed on a diet containing half as much thiamine as the diet of the A groups the carbohydrate index was 15 or greater in every instance and well above 15 in most cases. Definite diminution of the Achilles and patellar reflexes was observed in every subject of this group one to four months after the index first exceeded 15, and the index dropped precipitously within a few days after restorative treatment with yeast was instituted. This index of carbohydrate metabolism therefore appears to be a valid tool for diagnosing early and mild degrees of B vitamin complex deficiency. The probability that thiamine is the part of B vitamin complex responsible for the changes observed is very strong.[1] So far as is known the only important difference between the restricted diets given to the A and B groups was in the thiamine content. The riboflavin of the more restricted diet was only slightly less than the diet had provided for the A groups. Synthetic thiamine was used as the restorative therapy in only one subject of the B groups, but in this case there was an immediate drop in the index and an early amelioration of the clinical symptoms. The other subjects were treated with yeast extract; one of them, BY4, received only riboflavin for ten weeks. It is not implied that an index of 15 is the exact dividing line between normal and pathological states. Future work may show that the line may be a little higher or lower than this. Disorders of metabolism in which the so-called mild exercise test may be relatively strenuous for the individual concerned should be studied. High indices have been obtained in cardiovascular disorders and thyrotoxicosis. On the other hand, the diabetic not treated with insulin gives a very low index.

A by-product of the study of glucose and lactic and pyruvic acid levels in the old and young subjects was the confirmation of the observation that old men have higher glucose tolerance curves than young men. However, the generally accepted assumption that the rate of absorption of carbohydrates from the gastrointestinal tract is slower in old men could not be confirmed.

It has been shown that smaller amounts of thiamine and riboflavin are excreted in the urine of individuals on restricted diets and that the average excretions can be correlated with the extent of the depletion. However, the variations which occur between individuals make the results of urinary analysis for thiamine and riboflavin of little diagnostic significance except to assist in the evaluation of dietary consumption during the weeks preceding the test.

CLINICAL OBSERVATIONS

Mild restriction of B vitamin complex led to physical and mental changes in these chronically psychotic, mostly sedentary, old and young male subjects. The important physical changes were regressive changes in the skin, impairment of appetite, lowering of blood pressure, slight edema, dulling of vibration sense, and diminution of deep reflex activity. The predominant mental changes were decrease of psychomotor activity, dulling of attention, loss of interest and ambition, and seclusiveness. The development of both mental and physical signs and symptoms was exceedingly slow. No definite claim of changes could be made in the first year of the experiment. There was a difference in the resistance of the age groups in that only old subjects showed signs of circulatory insufficiency. Nerve involvement was also more pronounced and more persistent in the old. The subsequent therapeutic response to yeast extract administration was, in general, rather prompt as to feeling, interest, and appetite, rather slow, though distinct, as to deep reflexes, and hardly noticeable as to regressive skin change except for slight return of lost elasticity.

---

[1] Results to date in a subsequent project in which riboflavin only is restricted have indicated no changes in the index of carbohydrate metabolism.

Severe restriction of vitamin B complex in another group of rather sedentary, chronically psychotic old and young subjects led to severe physical and mental changes. The main physical changes were signs of circulatory insufficiency, of neuropathy, of disturbed gastrointestinal motility, loss of appetite, and changes in the appearance of the skin and tongue. The mental changes were chiefly characterized by loss of inhibitory emotional control, paranoid trends, manic or depressive features, and confusion. Both physical and mental changes were acute to subacute in onset. Sometimes the emotional manifestations were explosive in character. The physical and mental changes correlated well in the individual case with rise of pyruvate and lactate in the blood, especially in blood samples taken after exercise. The therapeutic response to subsequent yeast extract administration was dramatic as to appetite, circulation, gastrointestinal motility, appearance of tongue, certain aspects of sensibility (pains and paresthesias), and general display of energy. The recovery from loss of muscle power was rather prompt. Some sensory qualities showed slow return. In one case of unilateral foot drop the improvement was exceedingly slow. Slowest was the recovery of lost Achilles tendon reflexes. Noteworthy was the partial return of completely abolished patellar and Achilles tendon reflexes in one young man who received only riboflavin therapeutically. The explanation of this is not clear. The correlation of clinical improvement with the fall of pyruvate-lactate blood levels in the recovery period was as striking as the correlation of the deficiency syndrome and the rise in the pyruvate and lactate blood levels during the period of severe B vitamin restriction.

Marked dependent edema, with facial puffiness and serous effusion was observed in several subjects during severe restriction of B vitamin complex. This has no parallel in the investigation of other workers. The fact that the restriction was not so severe that it forced early disruption of the experiment may have contributed to the development of these features. Although the first subjects to show changes in the severe restriction phase were old men and the last subjects were young men, the small number of experimental subjects does not permit the generalization that old people under severe B vitamin complex deprivation will break faster or more seriously than young individuals. The old man who in more than six months of severe restriction showed little more than diminution of deep reflexes was the one who, at all times, exercised the least. This finding supports the view that physical activity has a precipitating effect on the development of B complex vitamin (thiamine?) deficiency disease. Many of the circulatory and nervous symptoms of our subjects bore a close resemblance to the symptoms of oriental beriberi as found in Vedder's classic descriptions.

NEUROLOGIC OBSERVATIONS

Determinations of vibratory sense by objective and quantitative methods were obtained. Although irregularly demonstrable in the young subjects of the A group, decreased acuity of perception of the vibrating fork on the lower extremities was noted at some time or other in all of the old subjects of the A group in the course of the three years of ***mild restriction of B vitamin complex.*** Other defects of the neurologic system were too irregular in mild deficiency to be of diagnostic value. With *severe restriction* of B vitamin complex there were numerous complaints of paresthesias of varied nature, such as tingling, numbness, itching, and pins and needles. Pain sensations, like paresthesias, were of a varied character. Burning sensations in some instances probably reached a degree of actual pain. Young and old members of the B group manifested these disturbances of superficial sensibility. Areas of hyperalgesia as well as patches and band-shaped zones of analgesia were found. Temperature sense also was impaired. An interesting observation was the loss of perception of pain induced by pin prick as contrasted with the increase of pain response when the skin of the same area was stroked with a wooden stick. It is of interest that all of the old subjects of the B group exhibited decreased acuteness of vibratory sense in the two years of B vitamin complex supplementation that preceded the period of severe restriction. This change perhaps was secondary to ageing. Curiously, in the period of severe B vitamin complex restriction there was increased perception of vibration. Paresis of the lower extremities was seen in young and old subjects in the period of severe restriction. One elderly subject exhibited a conspicuous bilateral steppage gait about five and one-half months after the restriction was instituted. At the same time another subject developed foot drop on one side. In several subjects there was a loss of proprioceptive faculties with development of ataxis of the lower extremities. In all subjects of the B group in the period of severe restriction there was decrease or loss of deep reflex responses. In four subjects there were complete abolition of knee and ankle jerks together with distinct diminution of the deep reflexes of the upper extremities.

PSYCHIATRIC OBSERVATIONS

Among the most outstanding changes observable in the subjects of these studies were those of the mental state. With moderate restriction of the B vitamin complex, mental changes came so gradually that it was difficult to know when they actually appeared. The most common was a dulling of faculties involving attention, interest, ambition, and sociability. This was associated with decrease of talking and slowing of movement. With severe restriction, mental changes were more sudden in onset and usually more severe in character. Members of the B group, both old and young, during the period of severe restriction displayed not only those abnormal mental reactions which were encountered among the less restricted subjects of the A groups but others of more explosive onset such as tantrums, furors, and rages. It must be re-emphasized that these subjects previously had psychotic patterns and one must conclude only this, that the nutritional deficiency reenforced or re-awakened psychotic trends and patterns.

Attitude and behavior declined for both old and young subjects during moderate restriction of B vitamin complex. Since there was a similar trend among subjects who received supplements of yeast extract during the first two years of study this trend suggests that the factor of boredom associated with the long-continued regimentation necessary for the experiment was in part responsible. A statistically significant drop in performance involving psychomotor skills was noted for the moderately restricted subjects but mental efficiency did not appear to be impaired to any significant degree. However, severe restriction of B vitamin complex was associated with a marked drop in attitude and behavior factors, and, for the majority of the old subjects, in mental efficiency. There were marked, individual differences in psychological reactions of the subjects of both mild and severe B vitamin complex deficiency. For each group, both old and young, both mildly and severely restricted, there were individual differences within the groups. The old subjects as a group were more affected than the younger subjects by the mildly restricted diet. This was true not only for test reactions, but also for performance tests stressing speed and manipulation as well as comprehension. However, ageing itself and the continuing deteriorative process of ageing throughout the three-year period of experimentation may well have played a part in this deterioration.

COMPARISON OF AGED AND YOUNG

Because previously published reports have seemed to indicate that the aged may have higher requirements than the young for vitamins of the B vitamin complex it was somewhat disappointing not to be able to arrive at a positive conclusion respecting this matter and thus to add a more positive chapter to geriatrics. The possibility remains that if the subjects of this study had been in a less protected environment and had done more work, greater differences between the old and the young groups would have been apparent. As it was, differences between individuals in the same age group were often greater than the differences between old and young. The investigators did obtain the impression that older individuals could not afford to remain on a severely restricted diet for long periods of time and a consideration of the risk involved led to supplementing the diet of the old men earlier than was done with the young, namely, as soon as any positive signs of nutritional deficiency became apparent. What might have happened if some of the older men had been held on the more deficient diet as long as some of the younger men remains a question which the necessity for caution leaves unanswered. Considering first the earliest phase of the study, before any dietary restrictions were instituted, one is impressed by the fact that the general levels of lactic and pyruvic acid were somewhat higher in the old than in the young. Though it could be demonstrated that these elevated levels were correlated with the higher basal and test glucose levels usually found in old individuals, it remains a probability that the older person lives with an amount of lactic and pyruvic acid which is high to start with, so that such a system, having less reserve, is more easily upset. The general assumption that the rate of absorption of carbohydrates is slower in the aged could not be confirmed. However, it is apparent, from the data here reported, that old men utilize carbohydrates more slowly than do the young. These differences correlate with the clinician's report that the aged showed signs of mild circulatory insufficiency and that in the young such signs were inconspicuous. The regressive changes in the skin, the lowering of the blood pressure, the slight edema, the dulling of vibration sense and diminution of deep reflexes were not sufficiently pronounced in mild deficiency to permit positive conclusion as to differences between the young and old groups; the observation that the subjects seemed to age faster on this mild deficiency should not be discounted. The psychological testing which indicated that the old subjects were in general more affected by the three-year mild restriction confirmed the general impression of those who saw the subjects daily. It was not possible to distinguish any significant variations in the response of the old and young to the more severe restriction. This may mean either that the extent of the chemopathological disorder was the same in both the old and the young, or that *the relative severity* of this deficiency led to such extreme reactions as to obscure the effects of age. The subsequent response of all subjects to therapeutic administration of yeast extract also was so marked that proof for the impression that older subjects had shown different recuperative powers was difficult to obtain. In spite of variability within the groups there remained the general impression of a difference in the resistance of the groups in that only old subjects showed signs of circulatory insufficiency and that nerve involvement was more pronounced and more persistent in the old.

GENERAL CONCLUSIONS

1. It is clearly evident from these studies that an intake of 400 micrograms of thiamine is below the minimal requirement of men who are relatively inactive and whose daily food consumption provides no more than about 2,000 calories.
2. The evidence respecting the adequacy of the amount of the riboflavin or other members of the B complex vitamin provided by the diets used was inconclusive.
3. That the aged are less resistant than the young to the ill effects of restriction of B complex vitamins is suggested, although not conclusively established. The evidence does not support the view that requirements for thiamine and other factors of the vitamin B complex are greater in the aged than in the young.
4. An effect of restriction of the B vitamin complex to a point where the intake of thiamine is less than the minimal requirement for thiamine is to intensify many of the neurologic and psychiatric symptoms of the mentally infirm.
5. Although the ill effects on mental health of inadequate allowances of thiamine and possibly of other B complex vitamins are conspicuous, there is nothing in these observations to support the view that very liberal provision of these vitamins is of therapeutic value in the treatment of mental disease.
6. A biochemical procedure is described, a metabolic load test, which offers promise of broad clinical usefulness in the diagnosis of early or mild and cryptic states of thiamine deficiency.

The National Research Council

Membership and Organization.—The National Research Council is a cooperative organization of scientific men of America, including also a representation of men of affairs interested in engineering and industry and in the basic sciences upon which the applications of science depend. Its membership is largely composed of accredited representatives of about eighty-five national scientific and technical societies. Its essential purpose is the promotion of scientific research and of the application and dissemination of scientific knowledge for the benefit of the national strength and well-being.

The Council was established at the request of the President of the United States, by the National Academy of Sciences, under its Congressional charter to coordinate the research facilities of the country for work on military problems involving scientific knowledge. In 1918, by Executive Order, it was reorganized as a permanent body for the general encouragement of scientific research.

BULLETIN
OF THE
NATIONAL RESEARCH COUNCIL
NUMBER 117 MAY 1949

NUTRITION SURVEYS: THEIR TECHNIQUES AND VALUE

PUBLISHED BY THE NATIONAL RESEARCH COUNCIL
NATIONAL ACADEMY OF SCIENCES
WASHINGTON 25, D. C.

PRICE $1.50

Announcements Concerning Publications
of the
National Research Council

The Proceedings of the National Academy of Sciences

is partly supported by the National Research Council which is represented officially on its Editorial Board and Executive Committee. It is open for the publication of papers to members of the National Research Council on the same terms as to members of the National Academy of Sciences

Subscription rate for the *Proceedings* is $5 per year. Business address: Home Secretary, National Academy of Sciences, 2101 Constitution Ave., Washington 25, D. C.

The Bulletin of the National Research Council

present monographs especially prepared by Committees of the Council or directories for general use in science compiled by the Council.

The *Bulletin* is published at irregular intervals. A discount of 20% from the list price of the *Bulletins* will be given to all who subscribe for the Series as issued, direct from the Publication Office. Numbers of the *Bulletin* are sold separately at prices based upon the cost of manufacture.

The Reprint and Circular Series of the National Research Council

renders available for purchase, at prices dependent upon the cost of manufacture, papers published or printed by or for the National Research Council. A discount of 20% from the list price will be given to all who subscribe for the Series as issued, direct from the Publication Office.

Orders for the *Bulletin* or the *Reprints and Circulars* of the National Research Council, accompanied by remittance made payable to the National Academy of Sciences, should be addressed: Publication Office, National Research Council, 2101 Constitution Ave., Washington 25, D. C.

A list of publications of the National Research Council with prices will be furnished upon request.

BULLETIN
OF THE
NATIONAL RESEARCH COUNCIL
NUMBER 117 MAY 1949

NUTRITION SURVEYS: THEIR TECHNIQUES AND VALUE

By
[illegible]

Committee on Nutrition Surveys,
Food and Nutrition Board
Division of Biology and Agriculture

PUBLISHED BY THE NATIONAL RESEARCH COUNCIL
NATIONAL ACADEMY OF SCIENCES
WASHINGTON, D. C.

FOREWORD

The Committee on Nutrition Surveys, which is responsible for the publication of this volume, was set up by the Food and Nutrition Board in April 1944, when a request for information concerning the methods by which the nutritional well being of the public could be periodically tested was received from the so-called Truman (Senate Investigation) Committee.

On many occasions during the war the Board had emphasized the need for a regular system of dietary and nutritional surveys of representative samples of the population to determine how the people were faring in the face of food rationing, scarcities of some common foods, interruptions and delays in food transportation, rises and declines in income and the cost of living, and the marked changes in working and living conditions brought about by the war.

The Board believed that information on the current dietary and nutritional status of the people would make it possible to frame the most suitable food policies, and to appraise and adjust these policies to the actual conditions and needs of the different groups in the population.

When the war ended, the Board refused to discharge the Committee, insisting that its work was just as important in peace as in time of war.

The Committee agreed to continue its work and in May 1946 presented to the Board the plan of the present volume. Like all publications of the Board and its committees, this volume is dedicated to the health of the American people; its purpose is to make available to doctors, health officers, nutritionists and all others concerned the latest information concerning the methods and value of dietary and nutritional surveys. It is the hope of all those who have been concerned directly or indirectly with this publication, that advances in our knowledge of nutrition and more precise methods of appraising nutritional status may soon make it necessary to prepare a new edition.

The publication of this volume does not bring the Committee's work to an end. It is simply one step on the road to better methods of appraisal and greater use of those methods in the campaign for better health through improved nutrition.

The Board is most appreciative of the unremitting efforts of the Committee and most grateful to the members for their individual contributions.

Frank G. Boudreau, M.D.
Chairman, Food and Nutrition Board

PREFACE

The problem of establishing and maintaining good food habits within a community or nation is exceedingly complex. In the first place, food consumption practices are subject to both gradual and sudden changes as a result of varying economic, social, political, and environmental factors. These changes may occur, furthermore, without consideration of the implications in regard to health. Cumulative effects of borderline malnutrition are so difficult to identify and may require so much time for recognition that there is constant need to be on guard against trends that involve risks of impaired health.

As a means of detecting and recording either favorable or unfavorable changes in nutritional status, provision should be made for periodic nutrition surveys of representative population samples by teams of experts. Such factual information would be invaluable to legislative leaders, public health officials, educators, physicians, agricultural economists, and those who guide the food industry.

It is hoped that the present monograph will be useful in developing a better understanding of the value and purpose of nutrition surveys and that it will contribute to the development and use of improved techniques for conducting such studies.

With each advance in discovering the nature and function of individual nutrients, scientists are in a better position to appraise the significance of differences in food practices. It is highly probable therefore that surveys will have increasing value in public health research and education in the years ahead.

The manuscripts used as a basis for individual sections in the monograph were prepared originally by individual authors, but extensive revisions were made on the basis of continued study and discussions by all members of the Committee. Hence each section has had the benefit of many suggestions and criticisms, including review by all members of the Board, before reaching its final form. Special acknowledgment should be made of the work done by the following authors in preparing the respective sections of the text: Section I, Dr. Elmer L. Sevringhaus; Section II, Dr. Hazel K. Stiebeling; Section III, Dr. Grace Goldsmith; Section IV, Dr. Herbert Pollack, Dr. Robert E. Johnson and Dr. Robert M. Kark; Section V, Dr. Frederick J. Stare, Miss Elizabeth Caso and Miss Frances McKinnon; Section VI, Dr. William J. Darby; and Section VII, Dr. Walter Wilkins and Miss Ruth Blakely.

C. G. KING, *Chairman*
Committee on Nutrition Surveys.

TABLE OF CONTENTS

PAGE
PREFACE.... iv
SECTION I: The Objectives and Demonstrated Value of Nutrition Surveys.... 1
SECTION II: Dietary Surveys and Their Interpretation.... 11
SECTION III: Chemical Tests and Their Interpretation.... 47
SECTION IV: Clinical Diagnosis in Nutrition Surveys.... 82
SECTION V: The Role of Surveys in Community Nutrition Programs.... 115
SECTION VI: Nutrition Surveys in Relation to Professional Training in Schools of Medicine and Public Health.... 126
SECTION VII: The Role of Health Departments in Nutrition Surveys and Appraisal.... 132

SECTION I

THE OBJECTIVES AND DEMONSTRATED VALUE OF NUTRITION SURVEYS

PAGE
Characteristics of Surveys........ 1
  Study of Distribution of Malnutrition........ 1
  Definitions of Malnutrition........ 2
  Objectives of Surveys........ 2
    Discovery of Vitamin Deficiencies........ 2
    Demonstration of the Biological Significance of a Particular Vitamin........ 2
    Determining Areas in Need of Treatment........ 3
    Determining Effective Dosage........ 3
  Use of Anthropometry........ 4
    Urgency of Good Statistical Methods........ 4
Use of Survey Techniques Combined with Prolonged Therapy........ 5
Surveys as Devices for Group Education........ 6

In late 1943, the National Research Council published a study (1) prepared by the Food and Nutrition Board which reviewed the evidence, gathered from 189 quoted publications, for dietary inadequacy and nutritional deficiencies in the United States. During the succeeding four years, reports have appeared that include experiences with population groups suffering deprivation of accustomed food intake by some of the vicissitudes of war. Interesting as these accounts are to students of nutrition, they are not comparable in value to the systematically organized surveys which are conducted expressly to secure data showing the distribution of cases of malnutrition. Surveys are also required to measure the comparative nutritive status of groups and communities. The characteristics of surveys can best be presented through examples recently published and therefore of current interest. Any student of the field ought to become familiar with the extensive dissertation (2) by Bigwood, prepared for the League of Nations and presenting a world point of view just prior to the Second World War.

Distribution may be studied from several angles. It has been interpreted in terms of geographic units, as in the North Carolina studies (3) or the Louisiana work (4), and it is of value to consider special population groups, such as the Mexican Indians (5). Populations can be appraised in various ways: requirements may be evaluated at different ages (6); the economic status has been involved in many cases (7); occupational groups became particularly important during the recent war (8); racial groups present special problems that justify their study (9). The adherence to distinct dietary customs or to taboos gives rise to opportunities for interesting surveys (10). Also groups under physiologic stress such as pregnancy (11) (43) (44), or pathologic stress such as complicating disease (12), are special objects of surveys. It is therefore obvious that the group to be surveyed must be defined. Upon the accuracy of this definition and the objectivity with which it can be applied in the field will depend the significance of the results. Such definition must be determined by the ultimate purposes of those who plan the survey.

Even more difficult is that definition of malnutrition which is to be used in a given survey. There are far more possible concepts of malnutrition than there are identified nutrients. The differentiation between excellent and barely acceptable nutrition with regard to any one nutrient adds complication. Marginal deficiencies are harder to detect, although they are apparently more frequent than the full-blown syndromes (13). A choice of standards which distinguish the bad from the acceptable states of nutrition must be made deliberately and in advance of the observations. This task is often more difficult than making the observations. Because there are numerous sources of disagreement among experienced students of human nutrition, free discussion on these matters should be invited in the planning of a survey, but ultimately the decisions about details should be made by a very small group to facilitate agreement. Since the detailed diagnostic standards are to serve for a specific survey and may not be permanently accepted standards, it is imperative that they be stated explicitly. Noteworthy efforts in this direction have been made by the U. S. Public Health officers (14). Further precautions include group training of the examiners if there are more than one. The experience of the team which studied a Newfoundland coastal group (15) gives eloquent testimony to the varied interpretations which even experienced examiners can place upon technical terms.

Most published results of nutrition surveys indicate that the purpose was to discover deficiencies of vitamins. The criteria for these deficiency states have included: (1) visible lesions supposedly associated with specific vitamin deficiencies; (2) laboratory data (such as blood concentrations, urinary excretions, or roentgenograms) showing conditions below accepted standards; or (3) food intake which compares unfavorably with published standards. The variety which the third approach may take has been reviewed by Stiebeling (16). The techniques of dietary surveys require clearer definition of their limits of precision, such as the evaluations made by McHenry and his co-workers (17) and by Kaser et al. (18). Furthermore, the reliability of a given method of dietary study should be ascertained for each region in which it is employed. The usefulness of such tabulated observations is greatly increased when two or all three criteria are applied in the same survey. Military organization has provided interesting examples of this combined approach (19). Recently some studies which are essentially surveys have incorporated treatment programs. This allows use of a fourth criterion, i.e., the results obtained by supplying specific nutrients in known dosage to those individuals whose evidences of deficiency have been recorded before therapy (20).

The aim of many surveys has been to demonstrate that certain lesions are resultants of specific deficiencies. Frequently the conclusions have been challenged, on a variety of grounds (21). The exact relation between one type of lesion and the supply of a specific nutrient is seldom constant in a large series of persons (22). This may be due to varying individual needs or variable intake of the foods carrying the particular factor, to the duration of the deficiency state (23), or to the participation of other conditioning factors. Among these last are varieties of trauma to tissues and also deficiencies of other nutrients. Recent reports reveal increasing realization of multiple deficiencies in spontaneous malnutrition (24), (25). Critical studies have shown that some lesions formerly thought to be specific indicators of single deficiencies can be produced by causes entirely non-nutritional, or can be cured by more than one vitamin (26). It has become evident that the therapeutic method can contribute much to the solution of the question if it is applied with adequate control series (27). By the very nature of the survey, designed to determine the nutritional status at a given time, this therapeutic technique is seldom possible. Consequently there is decreasing interest in using a survey as the method for detecting hitherto unrecognized clinical deficiencies and demonstrating their association with dietary intakes. The problem is made simpler, when the ultimate aim of a survey is to determine the distribution of probable deficiencies so that improved nutrition can be provided (28) (29). Theoretically there should be added to the criteria already mentioned a comparison between two groups, one of them supplied with generous amounts of the nutrients in question. Practically, the latter requirement is often supplied by the experience or general knowledge of the observers or of the readers of the survey. When the differences are not obvious, the survey is greatly improved by providing for explicit comparisons of two groups, adequately and suboptimally nourished (30). When the population to be studied in a survey has been subjected to prolonged or profound dietary restrictions, the criteria applied in physical examinations or chemical tests need not be as highly refined as when surveys are made of better-fed people. Thus, for example, such simple history-taking and physical examination as were possible for interned physicians working among fellow prisoners in oriental prison camps (31) enabled them to make valuable observations about "burning feet," a syndrome which is probably produced by a deficiency of pantothenic acid (32). Stringent requirements for correlation of lesions with single causative deficiencies can be relaxed in most surveys which aim to secure programs of better feeding for the surveyed population. This comes about since the deficiencies are seldom single. Usually it suffices to demonstrate the frequent occurrence of disorders of a group type, such as those due to inadequate intake of the B complex, rather than to prove deficiency of thiamine or of riboflavin separately (33). Therapeutic measures sought will usually provide improved intake, either of all the recognized nutrients (34) or at least of the several factors which are commonly associated in deficiency states.

It is possible to employ the survey technique in order to determine the minimum additions to a dietary program which will accomplish desired improvement in clinical condition. The technical problems involved have been carefully presented by a group of experienced students (35). Definition of lesions or of biochemical evidences must be as rigorous as possible. The group studied should be a population which will probably undergo a minimum of gain or loss in numbers, essentially an institutional population or an isolated community. Provision must be made for very careful statistical treatment of the data. Statistical methods are not a substitute for exact observation and recording; without exactness statistical methods are seldom justifiable. Precautions to ensure appropriate sampling are requisite unless the entire group is to be examined. Organization of the entire program in consultation with one trained in statistical methods may reduce wastage of effort. So, for example, it is possible to determine in advance the number of observations which will provide the desired degree of probability for any correlations to be established.

Perhaps the earliest surveys of nutritional status were the recordings of weight, correlated with height, age, and sex. These had an urgency supplied by the actuarial interest in the relationship between weight and the prognosis for morbidity from tuberculosis. Other chronic disorders came to be related to these same data. Later the pediatricians took up this approach as a measure of appropriate feeding of infants and children. Anthropometry as a detached and academic scientific approach provides many contributions. These are often stated as correlations with racial or geographic background, seldom with any nutritionally useful correlates.

For study of the relationships between height, weight, and age, suggested abbreviated standards will be found in the appendix to this chapter. There likewise will be found further bibliographic data for anyone desiring information on special populations or on more elaborate methods. Recent interest in such anthropometric data has become greater as the result of a number of observations made during and subsequent to the Second World War (36). For example, members of the Italian Medical Nutrition Mission, affiliated with the United Nations Relief and Rehabilitation Administration, in studies in Italy during 1945 became convinced that there was a significant reduction in stature for age of children from infancy through the adolescent years.[1] In order to validate and quantitate this impression, statistical methods would be required. Unfortunately the only data for a fair comparison with 1945 observations made in Naples were the reports published by a series of Neapolitans who had studied basal metabolism among children during the 1933 to 1940 period. By ignoring the probable differences in sampling between this group and the 1945 study, as well as other sources of error, it was possible to show that children in the first decade in 1945 were below the weights and the heights of the earlier period by approximately two standard deviations of the 1933–40 data. Although this leaves much to be desired as a careful estimate of the effect of malnutrition upon stature, it cannot but indicate the existence of the problem among Italian children. It is of interest to note at this point that certain clinicians, trained to make observations on nutritional status, had seen these Italian children but had been totally unimpressed with significant deviation from normal bodily build (37). Apparently, their attention was preoccupied with the lack of frequent emaciation or even evident thinness. The Italian children, who tend to plumpness (by American standards) when food is plentiful, had proportions between stature and weight which were not surprising to American observers. The Italian parents and physicians complained of the reduced weight of the children. It was only by applying the rough statistical methods and using standards of children in the same locality before the war that the stunting was made evident.

Analogous experience has been reported[2] from German children during 1946–47, and from Malaysian children during late 1945[3]. Although there were no satisfactory standard data on stature and weight of these Malaysian children, a helpful experiment was carried out in so short a period as ten weeks of feeding. One group was given a modest supplement of milk, another group the milk plus additional food chiefly as a source of calories. The increments in height of the groups were 0.35 and 1.13 inches respectively, and of weight 1.45 and 5.3 pounds. Improvement occurred likewise in the "specific signs" of vitamin deficiencies. Although these data offer no surprise to those grounded in animal nutrition experiments, they served to convince the local authorities of the existence of a problem in nutrition which could be met by simple and available means when the Japanese occupation had been terminated.

---

[1] Sevringhaus, Elmer L.: Unpublished observations.

[2] Gunther, Mavis: Unpublished observations. Personal communication.

The pre-existing standards for stature rendered the German observations more useful as data for subsequent scientific studies. Yet it is significant that in all three cases, Italian, German, and Malaysian, official and trained medical observers had denied the occurrence of marked nutritional handicaps in these populations after rapid and immediate inspections, whereas the subsequent measurements and comparisons with previous data gave evidence that the malnutrition coincident with the wartime conditions had left an inescapable mark on stature of children.

In addition to urging the careful recording of data and the statistical planning and treatment of the records contributed by such reports, another suggestion may be made. Those who have been involved in making the surveys just mentioned have become increasingly aware of the existence of great divergences in stature, in resistance to infectious diseases, in economic productiveness, and in initiative as individuals and groups. If the loss in these factors, which has been so evident in war-torn countries in even a brief period of a few years, is contrasted with the known increase in stature of American college students during the past 30 years (38) as well as with the decreasing morbidity from infectious disease and decreasing mortality among infants and children in America and Western Europe, some suggestions about nutritional surveys and therapeutic trials appear pertinent.

For example, may the supposedly racial types of stature and economic competence be in fact merely reflections of long-continued suboptimal nutrition? Such a question could be answered by a carefully planned combination of surveys with long-sustained therapy. It is not too difficult to find communities in Europe and the Orient where the population has little exchange of personnel with the nearby regions. If accurate data were recorded before and during a period of a few years of supervised supplementary feeding in one community, and other communities were compared as untreated controls, it would be possible to determine the importance of nutrition in some of these matters. If the experiment were planned on a broad enough scale, it is conceivable that relative physiological and economic advantages of different supplements could be determined. Thus the problem of which is the preferable adjuvant to a predominantly cereal diet—i.e., cereal germ, soya, or sun-flower seed—could be determined in the human where its solution is of the greatest importance. The advantage of a minimal amount of milk solids could be measured. Variations on this theme are numerous (39). The acceptability of the amended food patterns could be determined objectively (40). With planning of nutrition in world-wide terms, it is possible to accomplish important ends by experimental feeding which will harm no one and yet may secure information of tremendous importance, especially since a supply of generous amounts of high quality protein and of naturally occurring vitamins is not within sight.

---

[3] Bourne, Geoffrey, H.: Nutrition in Malaya under the Military Administration. Unpublished report. Oct., 1945.

Surveys have served to arouse the medical profession to recognize the existence of considerable numbers of individuals who suffer from malnutrition (41). An important example is the demonstration of the nutritional background for the occurrence of several of the hazards of childbirth and infancy (42) (43). Surveys have made large contributions toward convincing public authorities of the need for governmental interference in commercial practices to ensure better food supplies (44). The information required for educational efforts to improve food selection and preparation by the civilian public (16) or by the military authorities (45) has been derived in large part from surveys. These goals are worthy of further application of effort. The technique for a particular survey may well be determined by the choice of one or more of these goals. As the knowledge of nutrition becomes more

TABLE 1

HEIGHT—AGE TABLE

(Gray and Ayres)

AGE (YRS.)	BOYS		GIRLS	
	Av.	S.D.	Av.	S.D.
1	(18) 751.67	40.17	(12) 754.17	45.55
2	(21) 896.19	36.58	(21) 854.29	33.32
3	(28) 967.50	38.51	(23) 959.13	43.03
4	(34) 1046.76	53.13	(34) 1035.29	37.59
5	(74) 1111.76	43.13	(51) 1110.78	43.65
6	(114) 1185.88	48.50	(74) 1180.54	44.84
7	(143) 1247.24	52.31	(90) 1241.00	47.61
8	(147) 1310.65	52.81	(100) 1307.40	56.16
9	(167) 1358.35	58.10	(122) 1359.10	59.01
10	(173) 1411.88	51.31	(110) 1401.18	60.87
11	(201) 1454.35	66.17	(139) 1460.54	69.90
12	(247) 1503.50	67.37	(126) 1520.24	74.72
13	(293) 1564.49	72.88	(124) 1571.93	72.38
14	(373) 1624.14	77.93	(108) 1601.11	68.23
15	(362) 1684.61	77.32	(96) 1629.79	58.90
16	(292) 1728.43	67.10	(86) 1629.42	54.10
17	(229) 1751.68	61.45	(86) 1639.19	62.37
18	(129) 1761.51	63.99	(51) 1637.25	39.31
19	(52) 1763.46	57.22	(13) 1646.15	46.50

1) Each year is a mid-point, e.g., 2 yrs. = 1.5–2.5, and so on.
2) Numbers in parentheses = size of sample.
3) Measurements are in millimeters. (1 in. = 25.4 mm.)

complex the surveys of the future ought to be planned with greater definition of conditions observed, broader training of the observers in the conditions which may be correlated with malnutrition, and more careful statistical preparation for the collection and treatment of the data (46).

APPENDIX

The height-age (table 1) and weight-age (table 2) have been suggested by Prof. W. M. Krogman, Graduate School of Medicine, University of Pennsylvania, because they are considered representative. They were derived from a cross-section of North American middle-class population, predominantly of northwestern European ancestry. These tables are taken from "Growth in Private School Children," by H. Gray and J. G. Ayres, University of Chicago Press, 1931.

TABLE 2
WEIGHT—AGE TABLE
(Gray and Ayres)

AGE (YRS.)	BOYS		GIRLS	
	Av.	S.D.	Av.	S.D.
1	(18) 10.89	2.00	(12) 10.25	1.20
2	(21) 13.43	1.44	(21) 12.48	1.14
3	(28) 15.29	1.30	(23) 15.13	2.07
4	(34) 17.27	1.92	(34) 17.35	1.92
5	(74) 19.64	2.15	(51) 19.53	2.23
6	(114) 22.22	3.01	(74) 22.41	2.96
7	(143) 24.64	3.25	(90) 25.14	2.86
8	(147) 27.92	3.98	(100) 27.90	4.83
9	(167) 30.89	4.78	(122) 31.76	4.82
10	(173) 34.45	5.17	(110) 35.17	6.40
11	(201) 37.62	5.82	(139) 39.12	7.24
12	(247) 40.68	6.59	(126) 43.69	8.23
13	(293) 44.77	7.57	(124) 47.92	8.29
14	(373) 49.35	8.06	(108) 50.74	7.98
15	(362) 56.01	9.25	(96) 54.48	7.72
16	(292) 60.64	8.87	(86) 55.71	7.63
17	(229) 64.27	8.42	(86) 56.99	7.10
18	(129) 66.14	9.78	(51) 57.36	5.81
19	(52) 67.15	7.73	(13) 58.15	4.72

1) Each year is a mid-point, e.g., 2 yrs. = 1.5–2.5, and so on.
2) Numbers in parentheses = size of sample.
3) Weights are in kilograms (1 kg. = 2.2 lbs.)

For a compilation of extensive data on anthropometry from various countries reference should be made to "Growth of Man", by W. M. Krogman, which is Vol. 20, pp. 1–963 of Tabulae Biologicae, published by W. Junk, The Hague, Netherlands.

For recording changes in height and weight during surveys before and after nutritional therapy, attention is directed to "The Treatment of Growth Failure in Children", by N. C. Wetzel, published by N.E.A. Service Co., Cleveland, Ohio, 1948. This explains the use of the Wetzel "Grid."

BIBLIOGRAPHY

1. Food and Nutrition Board: Inadequate Diets and Nutritional Deficiencies in the United States: Their Prevalence and Significance. Nat. Res. Coun. Bull. No. 109, Nov. 1943. Reprinted in Am. J. Digest. Dis., *11:* 9–34, May, and 9–11, June, 1944.
2. BIGWOOD, E. J.: Guiding Principles for Studies on the Nutrition of Populations. Geneva. League of Nations Health Organization, March 1939.
3. MILAM, D. F. AND BELL, M. P.: Sources of Principal Nutrients in Diet of a North Carolina Village Population. J. Am. Dietetic Assoc., *22:* 411–414, 1946.
4. GOLDSMITH, G. A.: Nutrition Studies in New Orleans Area. Fed. Proc., *4:* 263–268, 1945.
5. ANDERSON, R. K., CALVO DE LA TORRE, J., SERRANO, G., AND PAYNE, G. C.: A Study of the Nutritional Status and Food Habits of Otomi Indians in the Mezquital Valley of Mexico. Am. J. Pub. Health, *36:* 883–903, 1946.
6. PIERCE, H. B., FENTON, P. F., WILKINS, W., NEWLAND, M. E., AND BUDGE, P. S.: Nutritional Defects Among Children in Vermont. New England J. Med., *233:* 612–617, 1945.
7. MUNSELL, H. E., CUADROS, A. M., AND SUAREZ, R. M.: A Study of Plasma Ascorbic Acid Values with Relation to the Type of Diet Used in Puerto Rico by Groups of Individuals of Widely Varied Economic Status. J. Nutrition, *28*: 383–393, 1944.
8. BORSOOK, H.: Nutritional Status of Aircraft Workers in Southern California. III. Effects of Vitamin Supplementation on Absenteeism, Turnover, and Personnel Ratings. Milbank Mem. Fund. Quart., *23:* 113–160, 1945.

   BORSOOK, H., DUBNOFF, J. W., KEIGHLEY, G., AND WIEHL, D.: Nutritional Status of Aircraft Workers in Southern California. IV. Effects of Vitamin Supplementation on Clinical, Instrumental, and Laboratory Findings, and Symptoms. Milbank Mem. Fund. Quart., *24:* 99–185, 1946.

   BORSOOK, H. AND WIEHL, D.: Nutritional Status of Aircraft Workers in Southern California. V. A Conspectus of the Survey and Its Field. Milbank Mem. Fund Quart., *24:* 251–291, 1946.
9. MOORE, P. E., KRUSE, H. D., TISDALL, F. F., AND CORRIGAN, R. S. C.: Medical Survey of Nutrition Among the Northern Manitoba Indians. Canad. Med. Assoc. J., *54:* 223–233, 1946.
10. BARNES, G. T.: Preliminary Studies in Nutritional Deficiencies. J. Trop. Med. & Hyg., *50:* 112–119, 1947.
11. DAVIDSON, L. S. P., DONALDSON, G. M. M., LINDSAY, S. T., AND ROSCOE, M. H.: Nutritional Iron Deficiency Anaemia in Wartime. Part III: The Haemoglobin Levels of School Children and Pregnant Women in 1944, Compared with the Levels in 1942 and 1943. Brit. Med. J., *2:* 333–334, 1944.
12. KIMBLE, M. S., GERMEK, O. A., AND SEVRINGHAUS, E. L.: Vitamin A and Carotene Metabolism in the Diabetic as Reflected by Blood Levels. Am. J. Med. Sci., *212:* 574–585, 1946.
13. DARBY, W. J. AND MILAM, D. F.: Field Study of the Prevalence of Clinical Manifestations of Dietary Inadequacy. Am. J. Pub. Health, *35:* 1014–1021, 1945.
14. SANDSTEAD, H. R. AND ANDERSON, R. K.: Nutrition Studies. I. Description of Physical Signs Possibly Related to Nutritional Status. U. S. Pub. Health Rep., *62:* 1073–1085, 1947.
15. ADAMSON, J. D., JOLLIFFE, N., KRUSE, H. D., LOWRY, O. H., MOORE, P. E., PLATT, B. S., SEBRELL, W. H., TICE, J. W., TISDALL, F. F., WILDER, R. M., AND ZAMECNIK, P. C.: Medical Survey of Nutrition in Newfoundland. Canad. Med. Assoc. J., *52:* 227–250, 1945.
16. STIEBELING, H. K.: Techniques of Finding Out What People Eat. Fed. Proc., *4:* 253–258, 1945.
17. YOUNG, C. M. AND MCHENRY, E. W.: Errors in Calculation of Nutritive Value of Food Intake; Comparison of Calculated and Determined Amounts of Ascorbic Acid. Canad. J. Pub. Health, *33*: 224–228, 1942.

   ——: Errors in Calculation of Nutritive Value of Food Intake; Comparison of Calculated and Determined Amounts of Iron. Canad. J. Pub. Health, *34:* 367–370, 1943.

   SEMMONS, E. M. AND MCHENRY, E. W.: Errors in Calculation of Nutritive Value of Food

Intake; Comparison of Calculated and Determined Amounts of Calcium. Canad. J. Pub. Health, *35:* 286–290, 1944.

18. Kaser, M. M., Steinkamp, R. C., Robinson, W. D., Patton, E. W., and Youmans, J. B.: A Comparison of the Calculated and Determined Calorie and Vitamin Contents of Mixed Diets. Am. J. Hyg., *46:* 297–325, 1947.
19. Kark, R. M., Aiton, H. F., Pease, F. D., Bean, W. B., Henderson, C. R., Johnson, R. E., and Richardson, L. M.: Tropical Deterioration and Nutrition. Clinical and Biochemical Observations on Troops. Medicine, *26:* 1–40, 1947.
20. Oldham, H., Roberts, L. J., and Young, M.: Results of Providing a Liberally Adequate Diet to Children in an Institution. III. Blood and Urinary Excretion Studies Before and After Dietary Improvement. J. Pediat., *27:* 418–427, 1945.
21. Anderson, R. K. and Milam, D. F.: Biomicroscopy of the Eyes in Evaluation of Nutritional Studies. Conjunctival Changes. J. Nutrition, *30:* 11–15, 1945.
    Ibid.: Corneal Vascularization. J. Nutrition, *30:* 17–24, 1945.
22. Youmans, J. B., Patton, F. W., Sutton, W. R., Kern, R., and Steinkamp, R.: Surveys of the Nutrition of Populations. 3. The Vitamin A Nutrition of a Rural Population in Middle Tennessee. Am. J. Pub. Health, *34:* 368–378, 1944.
    Ibid.: 4. The Vitamin D and Calcium Nutrition of a Rural Population in Middle Tennessee. Am. J. Pub. Health, *34:* 1049–1057, 1944.
23. Kruse, H. D.: A Concept of the Deficiency States. Milbank Mem. Fund Quart., *20:* 245–261, 1942.
24. Metcoff, J., Goldsmith, G. A., McQueeney, A. J., Dove, R. F., McDevitt, E., Dove, M. A., and Stare, F. J.: Nutritional Survey in Norris Point, Newfoundland. J. Lab. & Clin. Med., *30:* 475–487, 1945.
25. Harris, P. L., Hickman, K. C. D., Jensen, J. L., and Spies, T. D.: Survey of Blood Plasma Levels of Vitamin A, Carotene, Ascorbic Acid, and Tocopherols of Persons in an Area of Endemic Malnutrition. Am. J. Pub. Health, *36:* 155–160, 1946.
26. Stannus, H. S.: Some Problems in Riboflavin and Allied Deficiencies. B. M. D., *2:* 103–105, 140–144, 1944.
27. Spies, T. D., Perry, D. J., Cogswell, R. C., and Frommeyer, W. B.: Ocular Disturbances in Riboflavin Deficiency. J. Lab. & Clin. Med., *30:* 751–765, 1945.
28. Robinson, W. D., Payne, G. C., and Calvo de la Torre, J.: A Study of the Nutritional Status of a Population Group in Mexico City. J. Am. Dietetic Assoc., *20:* 289–297, 1944.
29. Biskind, M. S. and Williams, R. R.: Nutritional Survey at a Children's Institution; Incidence of Avitaminotic Lesions and Effects of Therapy. Am. J. Digest. Dis., *14:* 121–130, 1947.
30. Mack, P. B., Shevock, V. D., and Tomassetti, M. R.: Comparison of Meat and Legumes in Controlled Feeding Program. II. Medical, Dental, and Laboratory Observations. J. Am. Dietetic Assoc., *23:* 588–599, 1947.
31. Glusman, M.: The Syndrome of "Burning Feet" (Nutritional Melalgia) as a Manifestation of Nutritional Deficiency. Am. J. Med., *3:* 211–223, 1947.
32. Gopalan, C.: The "Burning Feet" Syndrome. Indian Med. Gazette, *81:* 22–26, 1946.
33. Milam, D. F. and Anderson, R. K.: Nutritional Survey of an Entire Rural Community in North Carolina. South. Med. J., *37:* 597–605, 1944.
34. Rhoads, T. F., Rapoport, M., Kennedy, R., and Stokes, J., Jr.: Studies on the Growth and Development of Male Children Receiving Evaporated Milk. II. Physical Growth, Dentition and Intelligence of White and Negro Children Through the First Four Years as Influenced by Vitamin Supplements. J. Pediat., *26:* 415–454, 1945.
35. Kruse, H. D., Bessey, O. A., Jolliffe, N., McLester, J. S., Tisdall, F. F., Wilder, R. M., and Sydenstricker, V. P.: Principles Underlying Studies of Nutrition Pertaining to the Influence of Supplements on Growth, Physical Fitness and Health, with a Comprehensive Bibliography of the Studies. Arch. Int. Med., *74:* 258–279, 1944.
36. Valaoras, V. G.: Some Effects of Famine on the Population of Greece. Milbank Mem. Fund Quart., *24:* 215–234, 1946.

37. Metcoff, J. and McQueeney, A. J.: Clinical Malnutrition in Italy in 1945. Nutritional Status of Selected Population Groups. New England J. Med., *235:* 451–460, 1946.

38. Mills, C. A.: Further Evidences of Reversal in Human Growth Tide. Human Biol., *13:* 363–377, 1941.

——: Oncoming Reversal of the Human Growth Tide. Science, *92:* 401–402, 1940.

39. Blair, R., Roberts, L. J., and Greider, M.: Results of Providing a Liberally Adequate Diet to Children in an Institution. II. Growth in Weight and Height. J. Pediat., *27:* 410–417, 1945.

40. Roberts, L. J., Blair, R., and Greider, M.: Results of Providing a Liberally Adequate Diet to Children in an Institution. I. Acceptance of Foods and Changes in Adequacy of Diets Consumed. J. Pediat., *27:* 393–409, 1945.

41. Pett, L. B.: Malnutrition in Canada. Canad. Med. Assoc. J., *50:* 9–14, 1944.

—— and Hanley, F. W.: A Nutrition Survey Among the School Children in British Columbia and Saskatchewan. Canad. Med. Assoc. J., *56:* 187–192, 1947.

42. Burke, B. S.: Nutrition and Its Relation to the Complications of Pregnancy and the Survival of the Infant. Am. J. Pub. Health, *35:* 334–340, 1945.

43. Smith, C. A.: The Effect of Wartime Starvation in Holland Upon Pregnancy and Its Product. Am. J. Obst. & Gynec., *53:* 599–608, 1947.

——: Effects of Maternal Malnutrition on Fetal Development. Am. J. Dis. Child., *73:* 243–244, 1947.

——: Effects of Maternal Undernutrition Upon the Newborn Infant in Holland (1944–1945). J. Pediat., *30:* 229–243, 1947.

44. Wilder, R. M. and Williams, R. R.: Enrichment of Flour and Bread. A History of the Movement. Nat. Res. Coun. Bull. No. 110, Nov. 1944.

45. Bean, W. B.: Nutrition Survey of American Troops in the Pacific. Nutrition Rev., *4:* 257–259, 1946.

——, Johnson, R. E., Henderson, C. R., and Richardson, L. M.: Nutrition Survey in the Pacific Theatre of Operations. Bull. U. S. Army Med. Dept., *5:* 697–705, 1946.

Kark, R. M., Bean, W. B., Aiton, H. F., Henderson, C. R., Pease, E. D., Johnson, R. E., and Richardson, L. M.: Tropical Nutrition. Biochemical and Clinical Observations on Troops. J. Clin. Invest., *25:* 927–928, 1946.

46. Anderson, R. K. and Sandstead, H. R.: Nutritional Appraisal and Demonstration Program of the U. S. Public Health Service. J. Am. Dietetic Assoc., *23:* 101–107, 1947.

SECTION II

DIETARY SURVEYS AND THEIR INTERPRETATION

PAGE
Introduction 11

Types of Food Consumption Data

Diets of Individual Persons 12
  Dietary history 13
  Estimates of food eaten, made by the individual 13
  Records of food eaten, kept by the individual 13
  Laboratory precision in measurements of food eaten 14
Family or Institutional Dietary Surveys 14
  Family food accounts 14
  Food record methods—quantitative measures and inventories 15
  Food list method—recall 16
  Economic versus physiological consumption of foods 16
  Total food consumption by family members 18
  Distribution of foods among family members 18

Some Points to Consider in Collection, Analysis and Interpretation

The Sample—Size and Representative Character 19
The Time Period to Which the Diet Relates 20
  Seasonal difference 20
  Day-by-day and week-by-week variability 20
Nutrients in diets 21
  What nutrients to measure 21
  Calculated vs. analyzed values 21
  Information on food values 23
  Variability in food values 23
  Nutritive value of mixed dishes 24
  Use of group values 25
Yardsticks of Adequacy and the Appraisal of Diets 25
  Some yardsticks of dietary adequacy 25
  Measures of nutritional need of the consumers in dietary surveys 26
  Using a yardstick to appraise diets 28
  Dietary studies in investigations of nutritional status 29
Some Additional Notes on Analysis of Family Dietary Surveys 30
  Variation in Family Size and Composition 31
  Consumption and Expenditure Scales 32
  Relation of Family Size and Food Consumption 33
  Current vs. Income for a Longer Period 34
  Home-Produced Food 35
  Dietary Patterns 36
  Family Dietary Surveys in Relation to National Food Supplies 36
Bibliography 37
Appendix 40

INTRODUCTION

Studies of food consumption are clearly an important feature of nutrition surveys. In fact one of the earliest approaches to an understanding of human nutritional requirements was through studies of the diets of persons in apparent good health. Thus the protein and calorie allowances suggested more than 75 years ago by Voit, the eminent German physiologist, were said to be based upon studies of the intake of laborers on freely chosen diets. Atwater in 1902 (1) proposed dietary standards in terms of protein and calories for adults of varying degrees of muscular activity. These, too, were based to a great extent on studies of the diets of individuals and boarding house groups in different occupations.

Today, even with the more precise laboratory and clinical procedures in use, knowledge of human requirements for many of the essential nutrients is far from complete. Since the state of nutrition (barring pathological conditions) clearly is dependent on previous food intake, its maintenance or improvement in the long run must come from food. Studies of the food consumption of individuals should be part of the appraisal of the nutritional status of individuals. It is important to broaden our understanding of what constitutes "normal" nutritional status and deviations therefrom, to determine the incidence of various deficiencies in the population, and to locate groups whose physical health and nutritional status are exceptional. It is also important to know what levels and patterns of dietary intake are associated with each.

In addition to dietary surveys made among individuals whose nutritional status is being appraised, there also are studies among institutional and family groups, ranging from small spot studies to those of nation-wide dimensions. Data from the latter surveys are of major interest to two groups: (a) those who wish to appraise dietary adequacy in order better to effect improvements in diets, and (b) those who seek to gauge potential markets for selected foods under various circumstances.

Many of the problems involved in the various methods of studying the nutrition of populations were discussed by Bigwood in 1939 (2). This chapter describes some of the more commonly used methods of collecting and analyzing data on food consumption and points out some of the uses of the results as well as some limitations to be observed in interpretation. The first two sections are devoted to a brief description of types of studies that use different methods to secure the original data regarding the kind and quantity of food that individuals or groups consume. Three sections follow which are equally applicable whether individuals or groups are the subject of study. These discuss some points to consider in the collection, analysis, and interpretation of data. Two additional sections describe methods of analysis that make family surveys serve many other purposes than appraisal of nutrition. The appendix contains pertinent sections of some of the schedule forms that have been used by different workers in the collection of data. They are included here as illustrations of the methods described rather than as recommendations for use.

TYPES OF FOOD CONSUMPTION DATA

Diets of Individual Persons.—Studies of the diets of individuals usually differ from family studies with respect to objective and in the methods used. Interest in individual studies always centers in foods actually eaten (physiological consumption) rather than in both the physiological and the economic aspects of consumption. Information about individual diets and food habits should tie in closely with studies of nutritional status, although the family dietary study can also make an important contribution.

Methods in current use for estimating the consumption of individuals range from a qualitative diet history or food habit inquiry to quantitative laboratory measure of the quantity and composition of the food eaten. Each type of study has its use; the important thing is to consider carefully what kind of facts are needed for a given purpose and which method will provide these facts at the lowest cost.

Dietary History.—This type of study aims to discover the usual food pattern over a relatively long period, as contrasted perhaps with a report of menus followed or quantities of different foods eaten in the previous 24 hours. This method should certainly reveal major deviations from the usual concept of good food habits. It would show up the non-milk drinkers, poor vegetable eaters, and the like. As such, it provides some indication of the direction of educational programs to improve nutrition. Even without any calculations of nutrient content, these histories can furnish a basis for classifying individuals into certain broad groups, for example, those whose diets are obviously poor with respect to one or more nutrients, those whose diets probably are better than the average, and an intermediate group.

Some investigators feel that dietary histories can be obtained with sufficient accuracy and completeness to justify calculation into terms of nutrients and appraisal of the individual's dietary practices.

Estimates of Food Eaten Made by the Individual.—In this method the child or other individual is asked to recall what he ate during a previous period, usually the last 24 or 48 hours. Sometimes he is asked for an estimate of the quantity of each food and various aids—pictures, food models, dishes and spoons of different size—are at hand to help in his judgment. This reporting of a day's food may or may not be accompanied by questions about food habits and whether or not this was a typical day. The greatest value of this kind of information is probably its use as a basis for educational or other programs to improve food habits.

Records of Food Eaten Kept by the Individual.—Many investigators have taught individuals to keep an accurate record of all food eaten during a period which may vary from one to seven days or more. Usually an attempt is made to get information on quantity as well as a full description of the food. These quantitative data differ in degree of precision. The quantity of food may be estimated or actually measured, using common measures; or the subjects may be taught to use balances or scales. Many modifications of this method have been developed to fit a particular need.

It is recognized that in this method, as in others, errors may arise at several points. The subject may fail to measure or estimate carefully the quantities of foods eaten or may keep a dishonest record; the analyst may err in translating the subject's quantitative measures or estimates into units employed in the food table used; the food tables may not be applicable in a given case.

However, several findings indicate that the carefully taken individual food record is of value in nutrition surveys. Darby (3) using 7- or 3-day records kept by individuals which included quantitative estimates of foods eaten found that the mean intakes of comparable populations showed close agreement and that the differences which occurred in segments of these populations were in the expected direction. Thus males consistently had a higher intake than females and the calculated ascorbic acid intakes were greater in higher than in lower economic groups (3), (4).

Finally, the more labile blood constituents, such as ascorbic acid and carotene, varied between groups in the same direction as the calculated intakes of these factors (4). A study of the statistical association between food intake of ascorbic acid and its level in the blood has revealed that the association is significant in three nutrition surveys made in quite different population groups (5). Hence, unless one expects too great accuracy from individual records, they seem to permit reasonably good characterization of the dietary habits of groups.

Laboratory Precision in Measurements of Food Eaten.—For many nutrition studies it is important to have precise information on the nutrient intake of individuals. This may mean a record by weight of food eaten in the home or under controlled group feeding, taken by a person trained in quantitative work who is mindful of and alert to possible sources of error. Actual laboratory analysis may be made of a duplicate of a meal eaten or of suitable samples of food. Because of the labor and cost of such studies their use usually is limited to extensive metabolic studies, or to research groups with special facilities for collection and analysis.

All of these methods furnish a certain amount of information about food habits, and give a more or less accurate indication of the probable nutritive value of the diet. There is need for a critical appraisal of the several methods in use in relation to the results obtained and their interpretation and application. Considerable experimental work comparing the usefulness of several methods in connection with surveys of nutritional status has been done but more extensive studies are needed.

Family or Institutional Dietary Survey.—Three general methods are open to the investigator wishing to study diets of families or other groups of individuals sharing common food supplies. They are:

(1) *Family food accounts.* Simple running reports of food purchased (and produced for household use).

(2) The *food record* which makes use of a weighed inventory of foods on hand at the beginning and close of the study, together with a day-by-day record (by weight) of food entering the home with or without records of kitchen and plate waste.

(3) The *food list,* which the interviewer uses in obtaining from the housewife an *estimate* of the quantities of foods used during the last 7 days.

These methods differ widely in the cost of collecting and analyzing data and in the uses that can be made of the results. In appraising these methods it is taken for granted that well-designed schedules are used, as well as procedures adapted to the habits of the group being investigated, and that adequate training is given to field agents or interviewers entrusted with securing the facts. No amount of analysis can compensate for inadequate original data. The unique characteristics of the methods are first described and then certain problems involved in the methods are considered.

Family Food Accounts.—Day-by-day records of food purchases and food expenditures can furnish valuable facts about family food consumption, especially among urban groups who keep comparatively little food on hand. This method was used during the war by the U. S. Bureau of the Census as a means of getting quick answers on how consumers were spending their ration points. Many farm families keep such accounts along with records of the food brought into the kitchen from storage or from the farm.

Advantages of this method include its simplicity since it can be easily understood by the homemaker keeping the account, and the relatively low cost of collecting such data. In households with small food inventories, where the diet is fairly monotonous and where food purchasing is pretty much hand-to-mouth, it would be unnecessary to keep food accounts for a long period to get a reliable picture of consumption. In other households, however, food accounts would need to be kept over long periods in order for inventories on hand at the beginning and end of the study to cancel.

Disadvantages include the difficulty of getting a random sample since participants must be willing and able to do the work required. Also interest may lag and participants drop out or become careless in their records to the point of affecting the validity of the results. In addition, the task of summarizing the data is considerable.

Since this method is not generally used in this country as a means of studying family diets, it will not be discussed further in this chapter.

Food Record Method—Quantitative Measures and Inventories.—The main characteristics of this method are the record by weight of food on hand at the beginning and the end of the period of observation, and the daily entry in the record of the weight of all foods coming into the house for household use. In order to maximize the accuracy of entries the trained field agent or supervisor takes the beginning and closing inventory. An accurate balance is left with the family. The homemaker or some other person is instructed carefully on how to make all entries. A record of menus is secured in order to check the reasonableness of food entries. The field agent visits the household frequently, often one or more times daily, to see that entries are properly made.

Even with daily visits of the field agent some omissions may occur. They may be quite marked in some situations; for example, among farm families a large quantity of the fruit consumed may not come into the house, such as watermelon and apples when these are plentiful in the garden or orchard.

Among the methods of securing food consumption data, the food record rates high in the possibility of securing accurate measures of food consumption for individual families as well as averages for groups of families. It has, however, several serious disadvantages. Repeated visits of the field agent may cause the diet to be altered, even though the family is urged to eat as usual. The agent may in fact unconsciously express disapproval or approval of certain types of menu. Her presence may lead the housewife to put on a good front by serving relatively large amounts of expensive foods or, among low-income groups secretly hoping to get material assistance, to deviate in the other direction. So far, no estimate has been made of the frequency or nature of such influences. There is some evidence, however, that families tend to reduce inventory of food on hand at the beginning of the period of observation, since in some surveys closing inventories of food on hand average less than beginning inventories. There is no evidence, however, that this tendency affects the quality or the cost of the diet.

Perhaps the most important limitation of the food record method is the burden it places on the cooperating household. As a result a relatively high proportion of families drawn in the sample may fail to provide a record. The proportion tends to be higher than average among families where the woman is away at work during the day, the homemaker is over 50 years of age, there is sickness or many small children in the family, or a hired cook in the kitchen. In addition, the burden of the method also decreases the likelihood of families being willing to provide another record later on.

One other disadvantage of the food record method is high cost, both in field collection and later tabulation. The repeated visits of the field agent, the high percentage of the sample failing to cooperate, and the need for assembling food quantities from the daily records all contribute to high cost.

Food List Method—Recall.—In this method a report is secured from the housewife of the estimated quantity by weight, retail unit, or household measure, of various foods consumed during the last seven days. The interviewer uses a schedule covering a complete list of foods. It has an advantage in that only a single and relatively short visit is required. As a result a high proportion of the homemakers contacted are likely to cooperate in reporting consumption, even in a repeat survey. The food consumption pattern is not affected by the continued presence of the field agent. In addition, the cost of this method is relatively low.

Sufficient comparison has not yet been made between the food list and the food record methods to permit definitive conclusions as to their relative accuracy. Such evidence as exists suggests that the food list gives a fairly accurate measure of the food bought or otherwise procured by individual families, though some understatement occurs. The quantity reported may be too small because the person reporting fails to recall that any of a certain food was consumed or that certain uses were made of it. Such omissions are likely to occur even when a carefully designed list is used, and when various techniques are used to help the housewife to recall the kinds and quantities of food used, such as by reviewing menus.

Even when all foods and the specific use of these are recalled, the estimate of quantity given may still be incorrect. However, for this type of error estimates from some families are likely to be too high and some too low, so that for averages for groups of families over-estimates and under-estimates may in large measure be offsetting. Also for an individual family, the over-estimates of some foods may partially offset under-estimates of others so that in terms of various nutrients errors may be less than for individual foods.

Because of low cost and other advantages the food list method has been used widely in obtaining information on the consumption of separate foods by *groups* of families, and in providing estimates of the average nutritive value of the food consumed by the groups. With improvement in technique, further comparison of results obtained by the food list and the food record may indicate the food list to be suitable for describing the diets of individual families. In any case, a bridge from the food lists to the food record can be built, if the chief interest lies in approximations of the consumption of population groups.

Economic Versus Physiological Consumption of Foods.—When foods move to the family kitchen whether from market or farm or garden, producers and sellers consider them as having been consumed. Not all of these foods are actually eaten by the family that bought them. Figures on economic consumption in terms of pounds of food tend to be considerably larger than physiological consumption, because some food may go into the garbage, to pets, may be carried home by servants, or be put to other use. For convenience in the discussion such food will be referred to as "waste."[1]

In some dietary surveys no information is secured as to waste. The extent to which such waste has been taken into account needs to be noted in interpreting the quantities of nutrients secured in various studies. For example, in the Consumer Purchases Study nonfarm families in the highest food expenditure group report 40 per cent more calories than estimated physiological requirement [(7) Table 44]. Since no account was taken of waste, it seems highly probable for many of these families that much of the food available for household consumption was actually not eaten. The data may represent a true picture of economic consumption but not of physiological consumption.

The food records now being used by the Bureau of Human Nutrition and Home Economics call for a daily estimate of food waste, and the food lists call for weekly estimates. Attempts to get a weighed measure of it continue to be made by some investigators. It is hoped that in time facts will be assembled to give a fairly reliable measure of the extent of food waste in the home. Reports from city garbage collectors suggest that from year to year it is highly variable in weight and composition.

How the question of waste is dealt with and what foods are wasted will affect the estimate of the nutritive quality of diets. In this country calorie estimates will be chiefly affected. Considerable fat in plate waste and drippings, and much stale bread go into the garbage. Only a small percentage of American diets are found to be inadequate with respect to calories, however. Calcium, a nutrient often short in diets, is not likely to be much affected, at least for urban families, unless milk goes to pets. For farm families the milk for the family and for chickens has not always been entirely untangled, so food consumption reported in some surveys may overstate calcium consumption.

Facts as to the edible food fed to animals and thrown away as garbage were obtained in a summer survey of a group of families in Georgia (8). Several diets classified as "satisfactory" before adjustment was made for the food entered in the record but not eaten by the family were classified "unsatisfactory" after such adjustment. Diets of white families of farm owners and tenants who fed their animals larger quantities of milk products than any other food were most seriously affected with respect to calcium and riboflavin. On the other hand, among low-income Negro families of farm sharecroppers and laborers grain products and fats, as well as some milk and vegetables, from the family food supply often went to animals. Their diets therefore were lower in food energy value and ascorbic acid than would have been indicated without the facts about food waste.

---

[1] This concept of waste ignores loss of nutrients because of method of cooking or because of failure to use the cooking water. Such losses are considered in relation to composition values to use in calculating nutrients rather than in measuring pounds of food consumed. Estimates of "waste" of food by consumers using a very broad interpretation is presented by W. Kling (6).

Total Food Consumption by Family Members.—Both the food record and the food list are especially designed to get facts on food consumption from families who eat most of their meals at home. Usually data are secured on number and type of meals eaten out and the expenditures for these and other foods eaten away from home by members of the family. In appraising the diet for nutritive quality, it is generally assumed that the food eaten out is similar in character and quantity to what was eaten in home meals. Among families where a large percentage of the meals are eaten out, this procedure is questionable, since meals eaten at home may be quite different from those eaten away from home. Further investigation is needed of the interrelation of food eaten at and away from home, and some pilot studies may well be undertaken.

To supplement data secured on food eaten out of the family food supply with a report on the additional quantities and kinds of foods eaten by family members may greatly increase the complexity of the dietary survey. One complication in such investigations is the fact that the housewife who provides the facts on the food eaten out of the family food supply—including lunches taken from home—usually does not know about the other foods consumed even when she knows how much money was spent for them. Facts about meals and other food purchased and eaten away from home thus must be secured from the members who consumed it. This may mean extra visits to interview the family members, or giving instructions to the homemaker for obtaining the information from these members. The method used might be that of recalling quantities of various foods eaten during the last day or two, or of keeping an actual record at the time the foods are eaten. Special techniques would be needed to get reasonably accurate estimates of quantity. It would be desirable also, but often impossible, to have data on ingredients in mixed dishes eaten away from home.

While it is perfectly feasible to obtain this information about foods eaten away from home by family members, the data themselves will seldom be as accurate as those on food consumption in the home obtained by the food record method. Furthermore the quantities will be on a different basis, foods "as eaten" rather than "foods as brought into the kitchen" which means special handling in computations and analysis. Nevertheless the increase in the proportion of meals eaten away from home makes this supplement to the family dietary survey increasingly urgent.

Distribution of Food Among the Family Members.—A dietary survey that gets facts only on the total quantities of food consumed by families tells nothing about the distribution of foods among family members. Observation suggests that it is not always distributed on the basis of need. Facts about distribution within a family for the most part call for special studies, although it is sometimes feasible in family dietary surveys to get some facts about it along with the usual facts on total family consumption. This has been done, for example, in a dietary survey made by the Bureau of Human Nutrition and Home Economics during 1946 and 1947 in Cumberland, Maryland, of families with school children in the third to the sixth grade. Facts bearing on distribution included menus, recipes, and quantity in household measure of each food eaten at home by the children in the third to the sixth grade.

SOME POINTS TO CONSIDER IN COLLECTION, ANALYSIS, AND INTERPRETATION

The Sample—Size and Representative Character.—The method chosen and the sample needed should be planned in the light of the kind of questions for which answers are sought, the response to be expected from consumers from whom facts are requested, and the funds available for both the field collection and the later processing of the data. The matter of purpose or use of the data is complex because dietary data have multiple uses that develop in part as the potentials of the data collected are recognized.

Many questions are likely to arise. In family studies, for example, it may be important to consider whether the descriptive data needed should cover all housekeeping families, or whether it might be desirable to concentrate on getting facts and figures designed to measure the effect of difference in income, family size, season, place of residence. If the latter seems best, it may be advisable to limit the types of family included. By getting a more homogeneous group the data will be more suitable for certain types of analysis.

The size of sample needed turns on what classification is to be made in analyzing the data and what foods are in need of special study. The lower the variability in consumption of a given food among families or individuals, the smaller is the number of families or persons needed to give stable averages. Because of the wide differences among foods in variability of consumption it will probably never be possible to have samples in family dietary surveys large enough to permit extensive analyses of all foods.

Random samples, in which every consumer or consuming unit has the same chance of being included in the study, are useful for describing the larger universe from which they are drawn. Non-random samples can also be used for this purpose if the distribution of characteristics in the larger universe that have a bearing on food consumption are known and if the non-random sample provides measures of consumption in terms of these. Even when non-random samples cannot be used as a basis of state and national averages, for example, they may if carefully used provide very valuable data for a study of the factors affecting food consumption and also of the nutritive value of the diet in relation to the known or estimated needs of the consuming groups.

In order to maximize the usefulness of data secured in surveys, it is highly important that the method of selecting the consuming units be fully described, along with facts as to those consumers drawn in the sample who were unwilling or unable to provide the information requested. Analysis may include a comparison of the characteristics of the sample with those of other samples or censuses. The U. S. Bureau of the Census publishes population characteristics and agricultural data showing many of the items by small geographic units, such as counties and townships. Appraisals of the sample are usually included in reports of surveys, such as those made by the Bureau of Labor Statistics (9) and the Bureau of Human Nutrition and Home Economics (7).

The Time Period to Which the Diet Relates.—Two aspects of the time period covered by a dietary survey seem especially important: (a) the difference among seasons, and (b) the day-by-day and week-by-week variability in diet quite apart from seasonal change.

Seasonal Difference.—Diets may vary greatly with season even in highly urbanized areas drawing food from many regions. This has been indicated by Stiebeling and Phipard in a study of diets of city workers' families in 1939 (10), and by studies of the Bureau of Labor Statistics (11). Even more variation occurs in rural areas where there is greater dependence on local or home-grown produce. Differences between fall and spring diets in rural Tennessee were shown by Kaser *et al.*, (12). Milam and Darby (13) presented data on food consumption in four seasons in a rural county in North Carolina. In addition, Milam (14) pointed out the seasonal changes in vitamin C blood levels which obviously reflect differences in seasonal intake.

These studies give some basis for gauging the effect of season on the nutritional quality of diets. Relatively little has been done, however, in following a group of families or individuals through the various seasons and getting a measure of the relative adequacy of average diets at different times during the year. In one such study in Czechoslovakia, the consumption of individuals in a farm family was recorded throughout an entire year (15).

The Bureau of Human Nutrition and Home Economics is at the present time comparing data from a small group of families in two seasons in one year so that diets in the two seasons may be compared family by family. A similar study of four families at four seasons was made several years ago.

In planning studies, then, to get an annual or even a complete seasonal picture, the collection of schedules should be spread throughout the year or season. Sometimes, however, it may be desirable to get seasonal extremes for comparative purposes, a sample of schedules then being taken at the height of each season. In any case, careful attention must be given to timing and selection of families or individuals in order suitably to diffuse other factors likely to affect consumption.

Day-by-day and Week-by-Week Variability.—If it should be determined that every day or every meal should carry a balance among certain nutrients, then it is important to get day-by-day reports. If it is sufficient, however, to have the diet adequate over a period of a week or longer, then the question is how long a period should the data cover in order to be sure that the average consumption per day or per week is a measure of customary behavior within a given season. In some societies the food may be so monotonous that a report covering a day or perhaps two at the most, along with feast periods coming a few times a year, may give a reasonably complete story. In the United States, however, a weekly pattern of food consumption is quite pronounced. As a result a period of at least a week is felt to be desirable to get a measure of the percentage of families having diets of a given nutritive quality.

It should be recognized that in any distribution of families or individuals by level of nutrient intake there will be fewer cases in the extremes when the data are based on seven days than on one or two days. In other words, there will appear to be fewer inadequate diets when the longer period is used.

The question is sometimes raised as to whether a period beyond seven days is needed (16) and if so, what is the best method to use in collecting data.

In a second week cooperation with a family food record would probably be low. A food list covering the past two weeks rather than the past week might result in too low a level of accuracy. It might be feasible to get families to cooperate in giving a 7-day food list for two successive weeks or for two weeks not too far apart. In making such a test it would seem best to keep the weeks within a season.

Nutrients in Diets.—What Nutrients to Measure.—The first question to decide in planning the analyses of any diet record for individuals or for families is which to include of the 40 or so nutrients needed by the body. Some nutrients are so widely distributed among foods or are sufficiently closely associated with others that not all need be considered in equal detail. Which should be considered will depend to a large extent on the nature of the diet. If the nutritive content of diets is to be calculated rather than analyzed, the availability of suitable food composition data must be considered. The investigation should consider also the yardstick to be used in interpreting the nutrient content of the diet. It may not seem worthwhile to calculate the quantities of a given nutrient for which no standards of intake have been proposed. On the other hand, such calculations will show the relative importance of selected foods or food groups as a practical source of the nutrient in question.

Whether or not it is desirable to calculate a given nutrient in a diet depends on whether or not it is likely to be deficient and on the intercorrelation of nutrients. For example, many studies have shown that it is safe to assume that if calcium and protein are adequately supplied, phosphorus also will be provided in sufficient quantity. However, although calories might never be low in a group being studied, it may be of interest to calculate the energy value of diets because of the relationship between energy metabolism or carbohydrate intake and the requirement for thiamine and other B-vitamins.

The intercorrelation of nutrients in diets is a subject which warrants further exploration. Any feasible reduction in the number of nutrients for which calculations are needed will aid in cutting the cost of analysis. It should be realized, however, that the omission of some nutrients may limit the possibilities for re-interpretation in the light of additional knowledge of interrelationships among nutrients.

Calculated vs. Analyzed Values.—Several investigators have compared the results obtained by computations and by analysis of representative samples of the diets being studied. Recognizing that there might be discrepancies, they wished to know how large these are and in what direction.

Results have led some workers to feel that agreement is remarkably good. For example, comparisons of the mean analyzed caloric value of individual diets with those calculated from modern food tables reveal that, despite differences between corresponding individual pairs, calculated and determined means may differ by less than 10 per cent. The agreement becomes better when the number of meals included is 20 or more, and when the intakes are measured on the raw basis (12), (17), (18). The calculated and determined means of protein in diets also show good agreement, usually within 5 per cent (17), (19), (18). Calculated values for fats in the diets generally tend to be higher than the values obtained by analysis (17), (18).

As to minerals, the reports of Widdowson and McCance (19) and of Hummel *et al.* (18) indicate that the calculated means of potassium are in excellent agreement with the analyzed means. The British workers also obtained good agreement for phosphorus, while according to Hummel *et al.* (18) the calculated amount of phosphorus exceeds the determined mean of the diet by 17 per cent. The use of calculations for determining the calcium and iron content of diets is somewhat more problematical. Semmons and McHenry (20) found for their 21 meals that the calculated means tend to exceed the determined means. This same tendency was observed by Gutman and Low (20) and Hummel and co-workers (18). On the other hand, Widdowson and McCance (19) found the opposite tendency, the analyzed values tending to be higher than the calculated. They attributed the discrepancy to the hard water used for cooking. When soft or distilled water was used for cooking, they obtained good agreement. According to them, the daily intake of calcium from water averages 75 mg. in England and may go up to 200 mg., depending upon the "hardness" of water. Actual intake of iron may exceed the calculated amount in the diets because of contamination during the process of food preparation, or because of differences in locality (19), (22). Kaucher and others reported the calculated to be approximately two-thirds of the actual intake in an iron-rich locality. On the other hand, for the 21 meals analyzed by Young and McHenry (23), the calculated content exceeded the actual mean content of 6.3 mg. by a difference of 0.6 ± 3.1 mg.

Perhaps the greatest discrepancies have been found and are to be expected in vitamin values because of wide natural variations and chance for loss in the handling of foods. Calculated ascorbic acid intakes are likely to exceed the actual determined values, particularly if the food tables employed are based upon uncooked foods (24), (12). When proper allowances for cooking loss are made and the means of a week's meals compared, the agreement between calculated values and determined values is brought within chance error, particularly when population groups are considered (12). Comparisons between the calculated and determined values of mixed diets for vitamin A, thiamine, riboflavin, and niacin indicate that, despite marked discrepancies which are sometimes found between the values for individual diets, the mean calculated figures may yield useful information for classifying a population into broad levels of intake.

When methods of analysis improve and more data are obtained on the effect of processing on vitamin content of foods, so that tables of the average composition of foods as served are available, the calculated values may agree more closely with the actual intake and become more useful.

In conclusion, it appears reasonable to agree with Widdowson and McCance (19) that "The results are considered to be sufficiently close to warrant the use of food tables in dietary surveys." This presupposes that the food intake is accurately measured, the length of period of study is sufficiently long, and proper food tables are applied. A food table is only valid for dietaries where the foods are similar in composition to, and are at the same stage of processing as, those from which the tables are derived. When nutrient values based on raw foods are used in calculation, the results should not be expected to agree with an analysis of foods as eaten, cooked or otherwise prepared.

Information on Food Values.—Carefully prepared and properly used tables of food composition are important in describing the nutritional quality of food supplies. Basic food composition values for calculating nutrients in foods as they come into the kitchen are available in a publication prepared in 1945 by the Bureau of Human Nutrition and Home Economics in cooperation with the National Research Council (25). Other sources of information exist and are used by some investigators in this country. Among the more commonly used sources are the tables of Bowes and Church (26), Taylor (27), Bradley (28), and Sherman (29). Values in the various tables are not always the same.

In other countries average composition figures for many foods are quite different from those used here. Some of the differences reflect real variations in the foods themselves. Others result from differences in methods of calculation from analytical data. For example, in the food tables commonly used in Great Britain figures for carbohydrates represent what is reckoned as available to the body for food energy. In the United States tables, total carbohydrate (by difference) is presented. As a result, quite different calorie values for a given food may be used in the two countries. These differences become of great practical importance in international programs involving calculations of food supplies and food requirements in terms of calories. The bases for computing calorie values were thoroughly reviewed by a committee convened in February 1947 by the Food and Agriculture Organization of the United Nations; suggestions were made as to the most satisfactory procedure for present-day use (30).

Variability in Food Values.—In deriving the average values presented in U. S. Department of Agriculture Misc. Pub. 572, the objective was to obtain representative figures for foods as used in this country the year around. Some of the averages in these tables rest on a large body of data and can be considered fairly stable. Others cannot be as well established until more analytical work is done.

Great variability exists in the nutrient content of foods, particularly for minerals and vitamins. Variety, soil, weather, and other cultural conditions, and length and kind of storage, are among the factors affecting the quantity of a nutrient in a given kind of food. Processing and methods of household preparation for eating exert still further influence. For some foods sufficient data are available for a study of the effects of some of these factors, and to provide separate averages for a specified type of condition. Take, for example, the vitamin C content of potatoes, an important item in diet calculations. In deriving the average value, 17 mg. per 100 gm. given in Misc. Pub. 572, over 1,100 analyses were examined. Individual samples ranged from as low as 4 mg. to as high as 40 mg. Data were available for studying losses in storage for varying periods. Thus the mean value for freshly dug potatoes was 24 mg. while for those stored 5 to 6 months it was 10 mg. per 100 gms. The development of a single figure for general use became a matter of appropriate weighting of values for fresh and stored potatoes of the important commercial varieties.

Nutrient losses due to cooking and other food preparation practices have been studied extensively in recent years. Enough is known to permit some rough adjustments to be made in dietary calculations to allow for these losses. However, the large number of variables to be taken into account and lack of information about food practices in the home are reasons why more precise allowances cannot as yet be made in calculating diets. When dealing with family food supplies, it may be desirable to compute the nutritive value with and without this adjustment. This permits comparison with other studies and easy revision as better information on the effects of food preparation becomes available.

When estimating the nutritive value of an individual's diet, food consumption data usually are in terms of food as eaten. Nutrient losses must then be taken into account in preparing the food tables to be used in calculation.

A question that faces every investigator is what, if any, adaptations of general food composition tables should be made for a particular study. In line with the objective of using the most representative figures for the diets being studied certain refinements are possible, particularly where studies are seasonal, local, and comparatively small. It might even be desirable to have special laboratory analysis of locally produced foods important in the diet of the group. The use of special values may be more important for diets of farm than of city families whose food supply in large part comes from diverse sections of the country. For example, values for raw instead of for pasteurized milk might be used in calculating farm diets. Season probably has a greater effect on the nutritive value of farm than of city diets. Different values for vitamin A in summer and in winter home-produced butter might be used. In the late winter or spring months, the average length of storage of potatoes eaten by farm families is much greater than that of potatoes eaten by urban families.

With each dietary study, the investigator wishes to use the most up-to-date and suitable food values. Food composition tables are revised frequently as more and more knowledge becomes available. But this frequently means that results of current and earlier studies are not directly comparable without recalculation. This underlines the importance of reporting in detail the quantities of food consumed. Recalculations can then be made as desired. It is important too that the factors used in calculating nutrients be included in the report or that reference be made to them if they are in a published table. Some estimates can then be made of the differences introduced by the use of specified nutrient values.

Nutritive Value of Mixed Dishes.—One source of error in dietary calculations is in estimating the nutritive value of mixed dishes. This problem is of special importance in the menu method of inquiry in which an individual estimates the quantity of each food eaten at a meal. It is almost impossible for him to know the kinds and quantities of ingredients in mixed dishes served at home and especially in public eating places.

In the family food record method, the housewife can supply the recipe for any mixed dishes on hand in the beginning or ending inventory and the ingredients can be figured with the household supplies. Estimates must still be made for mixtures which are purchased, such as baked goods, canned stews and soup mixtures, chicken and noodles, meat and bean combinations, and an ever increasing assortment of other food products. There is no standardization of preparation of these foods and the development of suitable food composition values presents a real problem.

Use of Group Values.—Short-cut methods of calculating diets, using weighted values for groups of foods closely related in nutritive value, have been reported by several workers (31), (32), (33), (34). Such a method has been used for over 15 years in the Bureau of Human Nutrition and Home Economics in the development of plans for adequate diets. Any technique which reduces the number of calculations saves time and cuts costs and should, therefore, be considered as a possibility.

The total amount of time saved depends on the number of diet records to be calculated. It is assumed that the results are to be studied diet by diet and not combined to give group averages only. Otherwise there would be little or no economy in a short method.

The development of appropriate group values requires preliminary study of the food consumption data in order to derive suitable weightings for the items combined into groups. In general, the larger the number of groups the more homogeneous the foods in each group can be, and the better the agreement between long and short methods. Also, the more days represented by the average consumption figures the closer the results obtained by the long and short method will be.

Group values developed in one study for use in one locality or in one season may not carry over to another and frequent testing against the more detailed item calculations is necessary. About 20 years ago the Bureau of Human Nutrition and Home Economics developed a short-cut method of calculating food energy, protein, and 3 minerals in family diets (35). The method was tested out on 121 dietaries (24 from institutions, 47 from farm families and 50 from other families). In every case the short-cut method gave figures for food energy within 5 per cent of the long method; for the 4 nutrients 85 per cent were within 5 per cent. However, when these group values were applied to 116 low-income dietaries from New York City and compared against the long method, agreement was much less good. For example, in the calculations for iron 47 per cent of the dietaries deviated by more than 5 per cent from results with the long method, with individual dietaries ranging from 25 per cent below to 55 per cent above the values obtained by the long method (unpublished).

On the other hand, Donelson and Leichsenring (32) reported several comparisons which showed excellent agreement, especially when means of groups were compared. Such good agreement can be expected only when food habits among the subjects are fairly homogeneous, i.e., when the proportion of specific foods selected within the food groups are similar, and when the food group values are carefully prepared.

Yardsticks of Adequacy and the Appraisal of Diets.—Some Yardsticks of Dietary Adequacy.—When quantities of food are translated into nutrients some yardstick is helpful for assessing the adequacy of these quantities for the people who consume the food. The standard selected may vary all the way from the minimum to prevent deficiency diseases to the amount needed to promote optimal nutrition. The so-called London Standard (36) drawn up in 1935–36 by the League of Nations

Technical Commission on Nutrition, represented the first attempt at international collaboration on dietary standards other than for calories. These standards are still used as a yardstick in many countries. But some other countries have developed different standards which they consider more applicable. In the absence of any generally agreed-upon standards many investigators have developed their own yardstick, or adopted one used by others. For example, the dietary standards developed by Stiebeling and Phipard (10) in 1939 were subsequently used by many other workers. A review of the evolution of dietary standards by Leitch was published in 1942 (37).

In this country the Recommended Dietary Allowances of the National Research Council first issued in 1941 (38) have served a useful purpose in providing a (single) yardstick which most workers in the United States have been glad to use. The objective and the bases underlying these allowances have been clearly set forth. They are intended as a guide in planning adequate diets for individuals or families. This means they were set high enough to provide adequately for the many persons with greater-than-average need. They may represent an unduly liberal margin in planning food supplies for large population groups in which the needs of part of the population are somewhat below the average and part above.

The value of a yardstick is contingent upon its proper use. Its changing character as a result of further research into nutritional needs should be recognized. Diets appraised with the yardstick of 1941 would need to be reappraised to make them comparable with diets appraised using the Recommended Dietary Allowances as revised in 1945 (39). While it is entirely correct to say that a diet or food supply provides the recommended allowances of nutrients for which quantitative suggestions have been specified, it does not necessarily follow that a diet which is calculated to provide these recommended allowances can be called "adequate." For one thing, not all the nutrients known to be needed in human nutrition have been included in the calculations. The allowances have been designed to apply to an average mixed diet such as is commonly eaten in this country. With any great deviation in the type of diet the recommended allowances may not apply. Furthermore, it is sometimes forgotten that the National Research Council allowances represent nutrients ingested and that most tables on food composition in common use in this country for dietary calculations refer to uncooked food as brought into the kitchen.

Recommended dietary allowances, like food composition data, are subject to revision from time to time as knowledge of human requirements unfolds. In any case, they can serve as additional means of description, and results expressed in terms of a standard *should not replace the more basic data—the quantities of various kinds of foods consumed or available for consumption, and quantities of nutrients provided by the food.* All too often the results of dietary studies are reported only in terms of the percentage of some standard of adequacy. Thus, they are tied to a measure which is itself subject to revision.

On the other hand, tables showing the distribution of diets according to the level of nutrient content have permanent value in that they can be interpreted in the light of any yardstick, present or future, in so far as the food composition values on which they are based have not undergone major revisions.

Measures of Nutritional Needs of the Consumers in Dietary Surveys.—Computations of the nutritive value of a diet are expressed in terms of some unit. When diets of individuals are studied this is not a problem since homogeneous groupings can be made and results expressed per individual. For family studies, however, averages per family per week may be compared directly only if the composition and requirements of the groups of families can be adequately described and are homogeneous except for not more than one important variable. Averages per person per day are often used and are easily understood. The usual procedure is to divide aggregate consumption for the week (or other period) by the number of meal-equivalent persons (21 meals = one person for one week) in the household. The per capita unit is generally satisfactory for comparing large numbers of families or homogeneous groups. It is not satisfactory for use in evaluating the diet of a given family nor for comparing diets of families of widely varying composition or activity.

To help in estimating the nutritional need of the individuals or families being studied, certain pertinent data are usually obtained. These include age, sex, height, and weight and may include information as to pregnancy and lactation. Sometimes an estimate of muscular activity is made. When the more accurate family food record method is being used, it is customary in studies of this Bureau to get information from which to gauge relative activity. It should be pointed out that requirements for food energy for an individual are very difficult to judge, and even the most careful estimates based on description secured from individuals may be far from the actual need. Nevertheless, a procedure taking activity, age, height, and weight into account is superior to that of assigning an arbitrarily predetermined value to food-energy standards.

When familites differ widely in composition and occupation, it is more satisfactory to estimate household size in terms of "nutrition units" (10). The "nutrition unit," with a value of 1.00, is usually assigned arbitrarily to the allowance of each nutrient recommended for a man who for size and activity requires about 3,000 calories daily. The values assigned to other individuals represent the relation that their allowance bears to the allowance for this man. Such scales, one for each nutrient, can be developed from the recommended allowances of the National Research Council. Household size is computed in terms of the number of energy units, calcium units, and so on, to fit the composition and energy needs of the family.

The following illustration for a specified family may serve to explain the calculation of household size in terms of energy and calcium units:

PERSONS	RECOMMENDED ALLOWANCE[1]		NUTRITION UNITS	
	Food energy	Calcium	Food energy	Calcium
	cal.	*gm.*		
Man, physically active	3,000	1.0	1.00	1.0
Woman, sedentary	2,100	1.0	.70	1.0
Boy, aged 13	3,200	1.4	1.07	1.4
Girl, aged 9	2,000	1.0	.67	1.0
Household size in nutrition units	—	—	3.44	4.4

[1] Recommended Allowances of the National Research Council, revised 1948 (40).

The effect of changing the recommended allowances for the adult man taken as unity should be clearly understood. For example, the previous allowance (1945) of 0.8 gm. of calcium for adults would have meant that the family listed above was equivalent to 5.0 calcium units instead of 4.4 units. The computation follows:

	gm.	units
Man	0.8	1.00
Woman	0.8	1.00
Boy	1.4	1.75
Girl	1.0	1.25
		5.00

The calcium content of this family's diet would calculate to be higher per nutrition unit when the value of unity was 1.0 gm. than when it was 0.8 gm. This illustration indicates the problems that may arise in comparing different studies when calculations of nutrient content are expressed in terms of nutrition units. They are only comparable when the scales of relatives have not changed.

One other problem confronts the analyst in determining whether the family food supply will provide the kind and amount of nutrients needed by the family group. As a rule, little is known about how the food is shared by persons in the household. To get this information adds considerably to the labor and cost of the survey. McHenry (41) in a study in Canada, found that the wage-earner had first choice, or at least came closest to meeting his calculated requirements, the young children next, then the older children, and the housewife. These families were all in a low-income group, but even among the relatively well-to-do, individual food habits and idiosyncrasies can bring about an unequitable distribution of household food supplies. This aspect of family studies needs further investigation.

Using a Yardstick to Appraise Diets.—Having selected a given yardstick to appraise diets, one must also decide what point or points along its range are to be accepted as providing diets of a given quality, perhaps to be described as good, fair, and poor, or as satisfactory and unsatisfactory.

Some investigators report the proportion of diets that provides, or fails to provide, the recommended allowances (NRC) for each nutrient. Others report also the proportion that provides or fails to provide some fraction—70 per cent, two thirds, one half, or other proportion—of these allowances. The important thing is to define what is used and to regard this appraisal as an additional but not basic feature of dietary analysis.

Diets classified as unsatisfactory or poor are usually so designated if they fall below the dividing line in even one nutrient. Some workers have felt that a diet low in one nutrient should not be in the same category as a diet low in several or all nutrients studied. Accordingly, several attempts have been made to develop a composite valuation which would give suitable weight to the several nutrients being studied. Some workers have computed the percentage of some standard allowance of each nutrient and have combined the several percentages into an average, either simple or weighted. In some cases more weight is given to the nutrients most likely to be low in the diets.

Dietary Studies in Investigations of Nutritional Status.—The ultimate test of the adequacy of diets is the long-term nutritional health of the people consuming them. Many nutrition surveys have been conducted in recent years and with the development of more rapid and more reliable methods such studies are expected to increase. A diet history as well as a record of the individual's current food consumption should be a part of the nutrition survey. Often the food record covers only a short period, from one to three days, and may represent varying degrees of accuracy.

The kind of correlation to be expected between dietary intakes and biochemical and other clinical findings has been the subject of much discussion. Lack of correlation between dietary intake and clinical condition may mean inadequate data, including errors in estimates of quantities of foods consumed and composition values of them; it may mean wrong interpretation of dietary or clinical data or both.

Some of the points to be borne in mind in such a comparison include the following: (a) The state of nutritional health at any one time represents the cumulative effect of food consumption over a long period as well as the recent intake of certain nutrients. The diet record may apply to a day or two, or a week. The great variation in an individual's diet from day to day and from week to week may invalidate attempts to closely correlate the two. However, some nutrients, such as ascorbic acid, are not stored in quantities sufficient to carry an individual through long periods of deprivation. In order that blood levels be maintained at their highest concentration, the frequent ingestion of ascorbic acid is necessary. Consequently tests for ascorbic acid levels in the blood may appear to give better correlation with the current diet record than is found in some other measures of nutritional status. Vitamin A, on the other hand, may be stored in quantities sufficient to maintain high blood levels for long periods of deprivation, and hence very little correlation may be found between recent intake and serum concentrations of this factor. Furthermore, signs of vitamin A deficiency may not be seen in individuals with temporarily low dietary intakes of this nutrient.

(b) The errors that may be introduced by applying tables of average food values to an individual's diet for a short period have already been indicated. These errors are magnified greatly if values for foods as they enter the kitchen are applied to foods as eaten. Perhaps even larger errors are inherent in the method of obtaining food consumption data from individuals.

(c) Only within broad limits can a judgment be made as to the adequacy of a calculated or determined dietary intake for a given individual. Wide individual differences in requirements are known to exist and in fact they may vary from time to time in the same individual.

Estimating food energy needs for subjects of dietary studies is particularly difficult. Since the requirements for some of the vitamins are related to energy metabolism, this may help to explain why evidence of vitamin deficiency does not appear in some cases where intake is apparently very low.

For these and other reasons one should not expect complete correlation between dietary intake over a short period and clinical or laboratory findings for an individual. For groups of persons, on the other hand, and for certain nutrients or aspects of nutrition, results may show fairly good agreement.

There is need for more surveys in which information about diets is secured along with facts about the state of nutrition. It is especially important that some of these be long-time studies, providing periodic checks on the same persons, if we are to enlarge our understanding of the relation of diet to nutritional health as measured by nutrition surveys.

SOME ADDITIONAL NOTES ON ANALYSIS OF FAMILY DIETARY SURVEYS

Analysis as it relates to methodology affecting the basic facts secured has already been considered. In this section attention is focused on the quantitative measurement of the relation of various factors to food consumption and dietary adequacy.

In planning the analysis of family dietary data, the analyst needs a broad knowledge of the behavior of families under a wide range of circumstances. In addition, he needs experience in working with the data. Only when these two qualifications are combined in an analyst are the necessary analyses likely to be designed that will peel off, as it were, and measure the effect of one factor after another.

The questions being asked the analyst of data of dietary surveys are many, even when one limits the list to those relating to actual and proposed food-consumption programs. Considerable progress has already been made, especially as to factors causing differences among families at a given point of time. Less has been done in studying the effect through time of various types of change. The former will be referred to as static and the latter as dynamic analysis.[2]

To the extent that sample size permits, data from dietary surveys have in very large measure been analyzed with respect to the following factors: Place of residence, especially farm and nonfarm groups and with some attention to size of city, food expenditure, income, family size and type, occupation of family members, extent of home-produced foods. To a lesser extent the response of consumers to relative prices of foods and changes in these and to food prices in relation to those of other consumer goods has been studied. At the present time there is need for further refinement of the analysis of most factors with special attention to discovering what uniformity if any exists from place to place among families at any point of time and from time to time in a given society. There is also need to compare the results of static and dynamic analysis, especially for such things as income, relative prices, and farm-nonfarm differences.

Because much attention has been given to the importance of income, the need for refinement in the analysis with respect to it seems great. There has, for example, been a tendency on the part of some persons when families are classified by income to ignore differences in family size. In addition, some persons have assumed that the measure of food consumption and dietary adequacy in relation to income as derived from a single study provides a true measure of elasticity of demand in relation to income—that is, the response of consumers to a change of income. Definitive analyses have yet to be made.

---

[2] This discussion is concerned only with the analysis of data from dietary surveys. Single surveys throw no light on the strength of food habits and the nature of attitudes to foods. However, important facts as to diet patterns are secured especially from family food records that include menus and from surveys of individual food consumption. Those interested in the importance of food habits and how to investigate them should consult bulletin of the National Research Council No. 111, "Manual for the Study of Food Habits," a report of the Committee on Food Habits.

The need for further refinement in the static type of analysis exists largely because of the multiplicity of factors involved. In measuring the effect of any one factor, complications are often encountered because other factors are not held constant. There are many correlations among the important factors affecting food consumption. For example, when families in the United States as a whole are classified by income, one finds within each income class variations in the size and composition of the families, in the percentage of families living in the various regions, and in the percentage living on farms, in villages, and in large cities (9) (42). The Consumer Purchases Study provided the largest sample ever secured in a dietary survey in the United States. Its potential for analytical purposes is still far from exhausted. However, even it does not permit complete analysis of the food consumption of groups of homogeneous families classified by season, type of community, region, and income.

In the analysis of data from dietary surveys, a major question is how far to sacrifice homogeneity of groups of families in each category in order to get larger numbers per category. It is probable that much can be done in isolating and measuring the effect of separate factors by using smaller and more homogeneous categories than have commonly been used and at the same time depending on the use of the entire sample in regression analysis to indicate the nature of the effect, rather than aiming to get averages for each cell that reflect the true facts of matters being investigated. In addition, insufficient use seems to have been made of multiple correlation. For the latter to be important, short cut methods need to be developed in order to minimize the cost of calculation.

While it is not possible here to review all aspects of the analysis of dietary data that have an important bearing on their interpretation, some of the broad questions as well as some of the analytical techniques have already been considered, and in the discussion that follows problems of classification with respect to family size and composition, expenditures, and income will be considered. These are major factors that lend themselves to statistical measurement within various non-quantitative groupings such as farm or nonfarm residence and occupation. In addition, some analytical problems relating to income and home-produced food are considered, as well as the problem of the statistical investigation of dietary patterns.

Variation in Family Size and Composition.—Diversity in the size and composition of families has always been a problem in consumption studies. The simplest method is to ignore the sex, age, and physical activity and count only persons, preferably on a week-equivalent basis. Families might, for example, be classified into perhaps six family-size groups and within each family size classified again by income. When that is done, the distribution by composition of family differs markedly from one size of income to another, but to a much smaller extent at the different income levels for a given family size (9).

If the sample is too small to permit the double classification by both family size and income, income and consumption averages per family at the various levels of family income can be reduced to averages per head. These averages are likely to give a somewhat more consistent picture than do the family averages, of the differences that occur if income were the only factor that differed among the categories. This is especially true of urban families, since for these a considerable increase occurs in number of persons per family at successively higher family incomes. However, deflation on a per-head basis tends to understate the difference in consumption that occurs with difference in income among families of a given size and composition.

In the analysis, for example, of dietary data in the light of the provisions of a proposed national food allotment bill, it was desirable to classify families by per capita income. When that was done, the large families, which on the average have a high proportion of young children and have the maximum advantage of economies in consumption that come with the larger group, tended to fall in the lower income categories. Small families, on the other hand, tend to fall in the higher income categories. The measure of elasticity of demand for many foods in relation to income derived by such analysis has a greater magnitude than if averages per head are derived after classifying the entire assortment of families by family income, or if the families are first sorted by size and measures of income elasticity derived for each size of family.

Consumption and Expenditure Scales.—The obvious differences in consumption needs of various family members early led to the development of consumption scales and the measurement of family size in terms of standard units (43). These are of two quite different types. For example, family size has been measured in terms of nutrition units in order to appraise the nutritive quality of diets. These have already been discussed (see p. 26). In addition, scales to measure the cost of providing equivalent consumption for the various family members have been developed for separate foods and services and for total consumption. Only two of these are considered here, namely, food expenditure or value and total expenditure scales. The former have been used to reduce the heterogeneity of family size and composition when the effect of expenditures for, or value of, food consumed is being investigated, and the latter have been similarly used for family expenditures or income.

If they serve the objective in mind, the value of such scales to measure the relative cost of food for different persons is very great. Scales so far developed, however, treat size of family solely as the sum of separate individuals, taking no account of their groupings into families. There seems little doubt that there are certain money economies with larger size of family. While this economy is much more pronounced for total consumption than for food, since housing included in total consumption is a major category of consumption which increases little with family size, even for food there are economies with larger size of family, and measures built up solely from scales of the separate individuals do not take this into account. This fact is indicated by the data given in table 1. The larger the family, the higher the percentage of families having good and fair diets and the lower the percentage with the poor diet at a given level of food expenditures per unit.

It may be possible to develop additional sets of food-expenditure scales that take into account the relative need of individuals separately and in various family combinations. Consumption units derived from scales for individuals as used at present are probably better for many purposes than per capita measures. The data in table 1 suggest that the expenditures scales used credit the large family with somewhat more units than it should have on a strictly equivalent basis, yet per capita measures would give them even more.

TABLE 1

PERCENTAGE OF FAMILIES OF SPECIFIED TYPES IN VILLAGES AND SMALL CITIES HAVING DIETS GRADED GOOD (OR FAIR) AT VARIOUS LEVELS OF EXPENDITURES PER FOOD-EXPENDITURE UNIT[1]

EXPENDITURE LEVEL PER UNIT PER WEEK AND REGION	FAMILY TYPES[2]			
	1	2 and 3	4	5, 6 and 7
$1.38 to $2.07				
North and West	16	25	28	30
South	30	32	21	41
$2.08 to $2.76				
North and West	57	71	62	70
South	56	62	85	75
$2.77 to $3.45				
North and West	86	89	89	90
South	84	85	89	88

[1] See Miscellaneous Publication 452, p. 57 (7). The higher expenditure levels were excluded because almost all families had good or fair diets.

[2] The family types (7), p. 16 are as follows:

Type 1	Husband and wife only
Types 2 and 3	Husband, wife and one or two children under 15 years
Type 4	Husband, wife, at least one child 16 years or over, and one or more of any age
Types 5 to 7	Husband, wife, and with at least two children under 16 years and some other children

Relation of Family Size and Food Consumption.—Using data from the Consumer Purchases Study and to a lesser extent those from other studies, two types of questions have been investigated: (1) At what income level does each family size achieve a specified quality of diet? (2) How does the quantity of food consumed or food expenditure differ according to the family size when income is held constant?

Data with a dual classification by income and family size or type permit preliminary answers to these questions. For example, it has been found, using data from the Consumer Purchases Study, that among families of two or more the size of income needed to yield the same percentage of families with good and fair diets for families of different sizes could be expressed by the following formula:

$$\text{Log } y = a + 0.62 \log x$$

where y is the amount of the income and x is the number of persons in the family (44). This measure takes into account family composition as it tends to be correlated with family size in a given urban society.

The change in food expenditures with family size while income is held constant has been studied by many. Published data are available for the development of such a measure of the effect of family size alone. When plotted on double logarithmic scales, these show linear relations of family size and food expenditures (45).

Even though considerable advance has been made in untangling the interrelations of family size and type, income, and food expenditures, there is still need for samples of families large enough to permit the analysis of one homogeneous family type at a time in relation to other facts. It may be that as data from various surveys accumulate they can be pooled to permit more effective measurement of differences from one type of family to another.

Current Income Versus Income for a Longer Period.—A dietary study usually covers food consumption for only a short period of time, often a week. The income reported often is that of the preceding year if the survey includes farm families and the preceding month for urban wage earners. Because incomes of families, especially in certain occupational groups, fluctuate a good deal, the question is frequently asked as to how the consumption of food as reported at a given income level would compare with what families would have eaten had all of them in the group fully adjusted their consumption to the income reported.

The assumption is commonly made that consumption and purchase of various goods lag behind change in income. If in a current survey any income class is heavily weighted with people whose incomes have recently increased, it may be that consumption is below what it would have been had the families on the average experienced this income for a longer period of time. The reverse of this condition may prevail if an income class is heavily weighted with families who until recently had a much higher income. The usual assumption is that the lag in consumption is greater when incomes are moving down than when they are moving up; in other words, the resistance to lowering consumption levels is greater than the hesitation in taking full advantage of increased incomes.

Only to a limited extent has this aspect of food consumption been explored and it should receive further attention. It does seem important to note that consumption and purchase of food tend to contract less with reduction in buying power than do the purchases of durable goods such as house furnishings; the use of the latter can be prolonged.

The bearing of year-to-year fluctuations in income, along with the difficulty of separating capital investment from farm expenses in getting a measure of net money income, has long been recognized as responsible in part for the very low income elasticity of demand for food found among many groups of farm families. The negative and very low positive income categories may include some well-to-do farm families who are classed as having low net money income, as a result of such farm expenses as the purchase of a tractor (or incurring a debt in order to acquire it). In this class also are farm families whose incomes are low because of recent crop failure. Consumption may be only slightly related to current income because such families may have large reserves on which to draw.

Year-to-year data from panels of farm families in midwest States show some of the dangers of interpreting current income as an indicator of the relation of income in general to consumption. In Kansas, for example, the correlation of average annual expenditures for food with current annual income for the years 1934 to 1941 was very low.[3] A higher correlation exists if the net income of the current and the preceding year were averaged. A still higher correlation was found with the gross income of the current and the preceding year. These higher correlations are partly due to the fact that Kansas farm families receive their income irregularly—the larger portion of their annual income is received during the last six months of a calendar year.

---

[3] This analysis is based on data in annual reports of accounts of Kansas farm families published by Kansas State College.

Home-Produced Food.—Home-produced food is usually important among farm families and introduces certain complications in dietary analysis. In most dietary surveys, the home-produced food is given a dollar value that is included along with the food purchased in the dollar value of foods consumed. This amount also is treated as nonmoney, and hence as a part of total income. Since farm family diets are often classified by both total income and value of food consumed, the prices used to impute a value to the home-produced food have a bearing on the magnitude of various relationships derived from analysis. The prices used in valuing these foods may range from farm sale to retail. Various inbetween prices may be selected. In the dietary surveys connected with the Consumer Purchases Study made during 1936–37 and Spending and Saving in Wartime during the spring of 1942, the prices used were those at the most likely place of purchase. These were somewhat less than retail prices since farm families in buying food get some of it from neighboring farms. In more recent studies a shift has been made to the use of farm sale prices. For the spring of 1942, the money value of home-produced food estimated at farm sale prices amounted to about 50 per cent of that estimated by using purchase prices.

The selection of prices to use depends in part on the purpose the data are to serve. If there is an interest in making the purchasing power per dollar of farm family income as nearly like that of the city family as possible, purchase rather than farm prices should be used to impute a value to home-produced foods. However, even when these are used, the purchasing power of dollars is still different and the consumption of such things as meat and milk by farm families is very high in relation to imputed prices. For many all-round economic analyses it is desirable to value food on the basis of the cost as seen by the family. For most foods this is the sale price which represents a measure of income foregone. To make farm-urban comparisons as to level of dietary adequacy achieved at a given level of real income, measures of relative costs of living are needed.

The importance of taking into account the prices used for imputation can be illustrated with data from the 1941 national dietary survey. At the net money income level of $1,000–$1,500, the value of total food consumed as a percentage of total income with two types of prices used for valuation is as follows:

IMPUTED PRICES	TOTAL INCOME	VALUE OF FOOD	FOOD AS A PERCENTAGE OF INCOME
Purchase	$1,783	$662	37 per cent
Farm sale[1]	1,600	479	30

[1] The value of home-produced food as reported in the U. S. Dept. of Agr. Misc. Pub. 520 was cut in two. This adjustment factor is based on a comparison of relative prices in U. S. Dept. of Agr. Misc. Pub. 550 that reports the data for a 7-day period in the spring of 1942 (42) (47).

Dietary Patterns.—The data from family dietary surveys provide a fund of information on dietary patterns. These are of quite different types. There are, for example, menu patterns, such as are commonly secured as part of the family food record, which can be analyzed to show the frequency of various food combinations. Data on the percentage of families in a given region consuming specified goods during the week of the survey also tell much about the diet patterns. In addition, statistical measures of interrelations of the foods and the nutrients in the diets are also of interest. Preliminary examination of the data from food records of nonfarm families reporting in the Consumer Purchases Study suggest that the relation of nutrients and foods in family diets as well as their interrelations are linear.

Some exploratory analysis of this type has been done through the multiple correlation of calories and selected nutrients with 11 food groups. Such an analysis, in addition to providing correlation and partial regression coefficients of the various foods and nutrients in family diets, provides a basis for developing food budgets within customary food habits. These can conform to selected levels of nutritive adequacy with or without regard to minimizing cost. Such analysis also provides a method of estimating the relative cost of food providing diets of specified nutritive quality for families of various types and among different types of communities.

FAMILY DIETARY SURVEYS IN RELATION TO NATIONAL FOOD SUPPLIES

Many uses for data from family dietary surveys have already been suggested in this chapter. An additional use is that of interpreting estimates of national food supplies and food requirements.

As one measure of food consumption, the U. S. Department of Agriculture periodically publishes estimates of yearly per capita consumption of various foods. These averages are derived from national aggregates of consumption based on statistics of production, foreign trade, inventories on hand, industrial uses, feed, seed, and estimates of losses in distribution between farm and kitchen. Calculations are made of the nutrient content of the per capita supplies available for direct human consumption. These data are especially useful for showing changes in consumption and for relating changes in the calculated nutrient content to shifts in consumption of different kinds of food or to some program such as the enrichment of flour and bread. Such an analysis covering a 37-year period was recently published (46).

Per capita averages include all the food that goes into institutions and public eating places as well as that which goes into the home, and pool the extremely good with the extremely poor in giving a single measure. The limitations of these data as a basis for judging the nutritional adequacy of national food supplies are obvious. For example, calcium is the only one of the 9 nutrients considered that during the 37-year period falls markedly below the recommended allowances of the National Research Council. However, dietary surveys of housekeeping families show a very different picture. The Consumer Purchases Study in 1935–36 indicated inequitable distribution for many foods and nutrients. The following statement briefly summarizes its findings:

> "About three-fourths of the families in the United States had diets that did not meet the National Research Council's recommendations for riboflavin and about half had diets that were low in calcium, thiamine, and ascorbic acid." (47)

Over-all national averages for 1942 indicate no deficiencies. Nevertheless, from dietary surveys it is estimated that in the spring of 1942 the diets of more than half of the families failed to meet the recommended allowances for riboflavin, although the proportion correspondingly low in calcium had been reduced to less than a third and the proportion low in thiamine, to a fourth (46).

National per capita averages nevertheless have value as indicators of relative adequacy. It seems highly probable that as national per capita averages of various nutrients change, all or almost all population groups are somewhat affected even though not equally. The per capita national averages are thus useful in indicating trends. If the distribution among population groups within various countries were about the same, and if the methods of calculation were comparable, national per capita averages would also be useful in indicating relative adequacy of diets among countries.

Figures on national per capita consumption combined with estimates of the quantities of different kinds of food needed to bring diets of poorly fed population groups up to some one or more recognized levels of nutritional adequacy also enable the nutritionist and food economist to indicate in quantitative terms the increases in consumption (and production) that might well contribute to improved national well-being. Such data, as well as trends in consumption and analyses of market demand under varying assumptions of incomes and prices, are basic in developing requirements for domestic production of and international trade in agricultural products.

BIBLIOGRAPHY

1. Atwater, W. O.: Principles of Nutrition and Nutritive Value of Foods. U. S. Dept. of Agriculture Farmers' Bull. No. 142, 1902.
2. Bigwood, E. J.: Guiding Principles for Studies of the Nutrition of Populations. Geneva. League of Nations Health Organization, Technical Commission on Nutrition, 1939.
3. Darby, W. J.: The Influence of Some Recent Studies on the Interpretation of the Findings of Nutrition Surveys. J. Am. Dietetic Assoc., *23:* 204–210, 1947.
4. Darby, W. J., Hahn, P. F., Kaser, M. M., Steinkamp, R. C., Densen, P. M., and Cook, M. B.: The Absorption of Radioactive Iron by Children 7–10 Years of Age. J. Nutrition, *33:* 107–119, 1947.
5. Putnam, P., Milam, D. F., Anderson, R. K., Darby, W. J., and Mead, P. A.: The Statistical Association Between the Diet Record of Ascorbic Acid Intake and the Blood Content of the Vitamin in Surveyed Populations. In press.
6. Kling, W.: Food Waste. J. Farm Economics, *25:* 856–857, 1943.
7. Stiebeling, H. K., Monroe, D., Phipard, E. F., Adelson, S. F., and Clark, F.: Family Food Consumption and Dietary Levels, Urban and Village Series. U. S. Dept. of Agriculture Misc. Pub. 452, 1941.
8. Bureau of Human Nutrition and Home Economics, U. S. Dept. of Agriculture. Unpublished data.
9. U. S. Bureau of Labor Statistics: Family Spending and Saving in Wartime. U. S. Dept. of Labor Bull. 822, 1945.
10. Stiebeling, H. K. and Phipard, E. F.: Diets of Families of Employed Wage Earners and Clerical Workers in Cities. U. S. Dept. of Agriculture Circular 507, 1939.
11. U. S. Bureau of Labor Statistics: Family Expenditures in Selected Cities, 1935–36. Vol. II, Food. U. S. Dept. of Labor Bull. 648, 1940.
12. Kaser, M. M., Steinkamp, R. C., Robinson, W. D., Patton, E. W., and Youmans, J. B.:

A Comparison of the Calculated and Determined Calorie and Vitamin Contents of Mixed Diets. Am. J. Hyg., *46:* 297–325, 1947.

13. Milam, D. F. and Darby, W. J.: The Average Diet of a Southern County and Its Effects on Nutritional Status. South. Med. J., *38:* 117–125, 1945.

14. Milam, D. F.: A Nutrition Survey of a Small North Carolina Community. Am. J. Pub. Health, *32:* 406–412, 1942.

15. Pelc, H. and Podzimkova-Rieglová: L'Alimentation d'une Famille Agricole Slovaque d'Après sa Consommation Alimentaire Relevée Pendant une Année. Les Trouveaux de l'Institut d'Hygiène Publique de l'Etat Ichécoslovaque, No. 4. Prague. October 1934.

16. Children's Fund of Michigan: Proceedings of Conference on Methods of Evaluating Nutritional Status of Mothers, Infants and Children. Detroit. February 1947. (Mimeo.)

17. Patterson, J. M. and McHenry, E. W.: Errors in the Calculation of the Nutritive Value of Food Intake. I. Comparison of Calculated and Determined Amounts of Calories, Protein and Fat. Canad. Pub. Health J., *32:* 362–365, 1941.

18. Hummel, F. C., Shepherd, M. L., Galbraith, H., Williams, H. H., and Macy, I. G.: Chemical Composition of Twenty-Two Common Foods and Comparison of Analytical with Calculated Values of Diets. J. Nutrition, *24:* 41–56, 1942.

19. Widdowson, E. M. and McCance, R. A.: Food Tables: Their Scope and Limitations. Lancet, *1:* 230–232, 1943.

20. Semmons, C. M. and McHenry, E. W.: Errors in the Calculation of the Nutritive Value of Food Intake. IV. Comparison of Calculated and Determined Amounts of Calcium. Canad. J. Pub. Health, *35:* 286–290, 1944.

21. Gutman, A. B. and Low, M.: On the Approximation of the Calculated to Determined Calcium Content of Human Dietaries. J. Nutrition, *18:* 257–263, 1939.

22. Kaucher, M., Moyer, E. Z., Harrison, A. P., Thomas, R. U., Rutledge, M. M., Lamec, W., and Beach, E. F.: Nutritional Status of Children. VII. Hemoglobin. J. Am. Dietetic Assoc., *24:* 496–502, 1948.

23. Young, C. M. and McHenry, E. W.: Errors in the Calculation of the Nutritive Value of Food Intake. III. Comparison of Calculated and Determined Amounts of Iron. Canad. J. Pub. Health, *34:* 367–370, 1943.

24. Young, C. M. and McHenry, E. W.: Errors in the Calculation of the Nutritive Value of Food Intake. II. Comparison of Calculated and Determined Amounts of Ascorbic Acid. Canad. J. Pub. Health, *33:* 224–228, 1942.

25. Bureau of Human Nutrition and Home Economics in Cooperation with National Research Council: Tables of Food Composition in Terms of Eleven Nutrients. U. S. Dept. of Agriculture Misc. Pub. 572, 1945.

26. Bowes, A. de P. and Church, C. F.: Food Values of Portions Commonly Used. 5th Ed. Philadelphia. Philadelphia Child Health Society, 1944.

27. Taylor, C. M.: Food Values in Shares and Weights. New York. The Macmillan Company, 1942.

28. Bradley, A. V.: Tables of Food Values. Rev. Ed. Peoria, Ill. Manual Arts Press, 1942.

29. Sherman, H. C.: Chemistry of Food and Nutrition. 7th Ed. New York. The Macmillan Company, 1946.

30. Food and Agriculture Organization of the United Nations: Energy-Yielding Components of Food and Computation of Calorie Values. Washington, D. C., May, 1947.

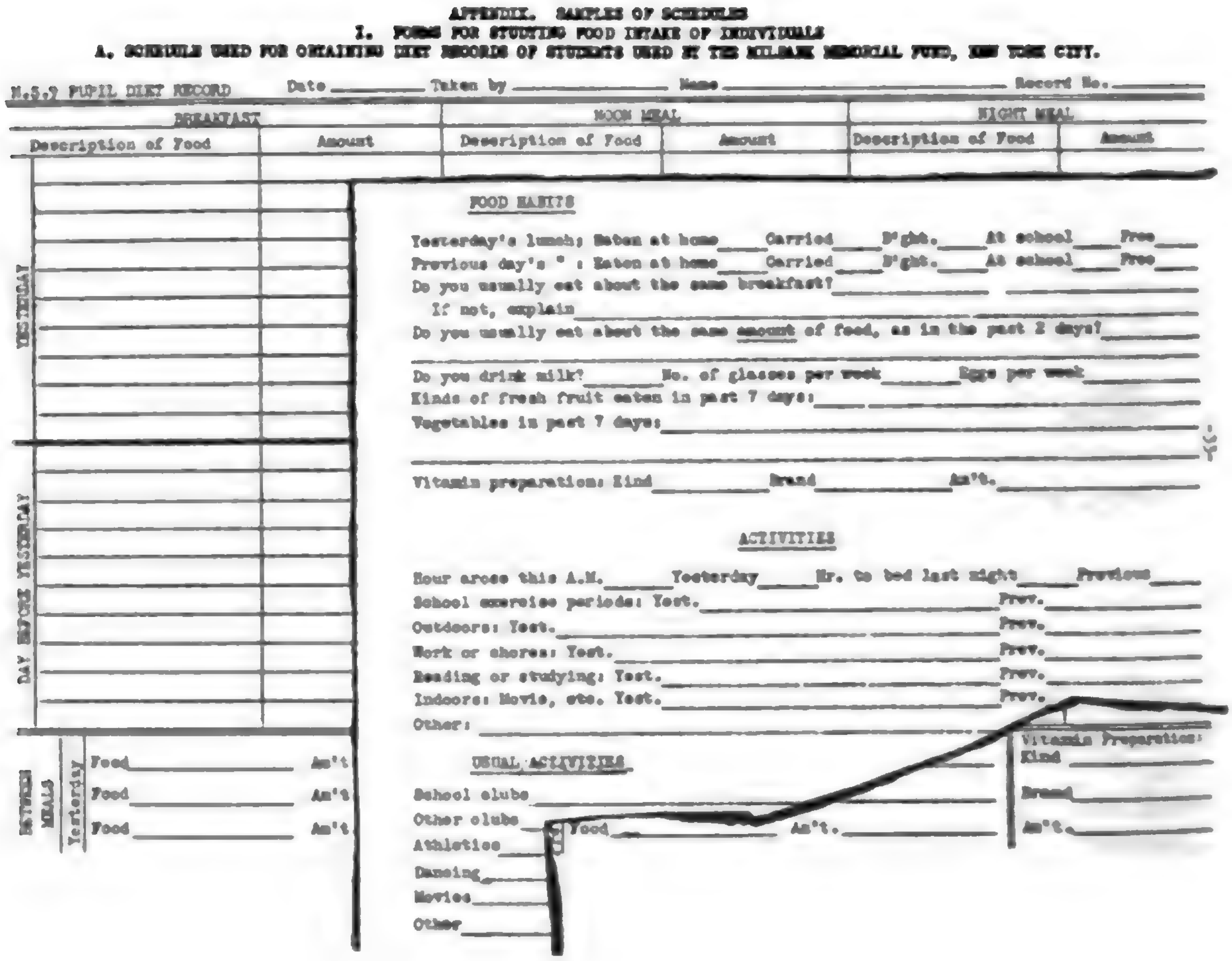
31. Berryman, G. H. and Chatfield, C.: Short Method of Calculating the Nutritive Value of Diets. J. Nutrition, *25:* 23–37, 1943.

32. Donelson, E. G. and Leichsenring, J. M.: A Short Method for Dietary Analysis. J. Am. Dietetic Assoc., *18:* 429–434, 1942.

33. Donelson, E. G. and Leichsenring, J. M.: Food Composition Tables for Short Method of Dietary Analysis (Revised). J. Am. Dietetic Assoc., *21:* 440–442, 1945.

34. Steinkamp, R. C., Robinson, W. D., and Kaser, M. M.: Adaptation of Short Method of Calculating the Nutritive Content of Diets in Rural Areas in Middle Tennessee. J. Am. Dietetic Assoc., *21:* 522–526, 1945.

35. HAWLEY, EDITH: A Short Method of Calculating Energy, Protein, Calcium, Phosphorus and Iron in the Diet. U. S. Dept. of Agriculture Tech. Bull. 105, 1929.
36. League of Nations: The Problem of Nutrition. II. Report on the Physiological Basis of Nutrition. Ser. League of Nations Publication II-B-4, Geneva, 1936.
37. LEITCH, I.: The Evolution of Dietary Standards. Nutr. Abst. & Rev., *11:* 509–521, 1942.
38. Food and Nutrition Board: Recommended Dietary Allowances. Nat. Res. Coun. Reprint and Circular Series No. 115, January 1943.
39. Food and Nutrition Board: Recommended Dietary Allowances, Revised 1945. Nat. Res. Coun. Reprint and Circular Series No. 122, August 1945.
40. Food and Nutrition Board: Recommended Dietary Allowances, Revised 1948. Nat. Res. Coun. Reprint and Circular Series No. 129, October 1948.
41. MCHENRY, E. W.: Nutrition in Toronto, Canada. Canad. J. Pub. Health, *30:* 4–13, 1939.
42. Bureau of Human Nutrition and Home Economics: Rural Family Saving and Spending in Wartime. U. S. Dept. of Agriculture Misc. Pub. 520, 1943.
43. REID, M. G.: Food for People. New York. John Wiley and Sons, Inc. 1943.
44. United States Congress. Joint Committee on International Revenue Taxation: The Taxation of Pensions and Annuities. Washington. 79th Congress, 2nd Session, H.R. 2948. 1946. p. 56, illus.
45. BRADY, D. S., MONROE, D., PHELPS, E., AND RAINBOTH, E. D.: Family Income and Expenditures, Five Regions. Part 2. Family Expenditures, Urban and Village Series. U. S. Dept. of Agriculture Misc. Pub. 396, 1940.
46. CLARK, F., FRIEND, B., AND BURKE, M. C.: Nutritive Value of the Per Capita Food Supply, 1940–45. U. S. Dept. of Agriculture Misc. Pub. 616, 1947.
47. Bureau of Human Nutrition and Home Economics: Family Food Consumption in the United States, Spring 1942. U. S. Dept. of Agriculture Misc. Pub. 550, 1944.



APPENDIX. SAMPLES OF SCHEDULES

I. FORMS FOR STUDYING FOOD INTAKE OF INDIVIDUALS

A. SCHEDULE USED FOR OBTAINING DIET RECORDS OF STUDENTS USED BY THE MILBANK MEMORIAL FUND, NEW YORK CITY.

M.S.9 PUPIL DIET RECORD Date ______ Taken by ________ Name ____________ Record No. ______

	BREAKFAST		NOON MEAL		NIGHT MEAL	
	Description of Food	Amount	Description of Food	Amount	Description of Food	Amount
YESTERDAY						
DAY BEFORE YESTERDAY						

BETWEEN MEALS Yesterday
Food ________ Am't
Food ________ Am't
Food ________ Am't

FOOD HABITS

Yesterday's lunch; Eaten at home ___ Carried ___ B'ght. ___ At school ___ Free ___
Previous day's " : Eaten at home ___ Carried ___ B'ght. ___ At school ___ Free ___
Do you usually eat about the same breakfast? ________
If not, explain ________
Do you usually eat about the same amount of food, as in the past 2 days? ______
Do you drink milk? ____ No. of glasses per week ____ Eggs per week ____
Kinds of fresh fruit eaten in past 7 days: ________
Vegetables in past 7 days: ________
Vitamin preparation: Kind _____ Brand _____ Am't. _____

ACTIVITIES

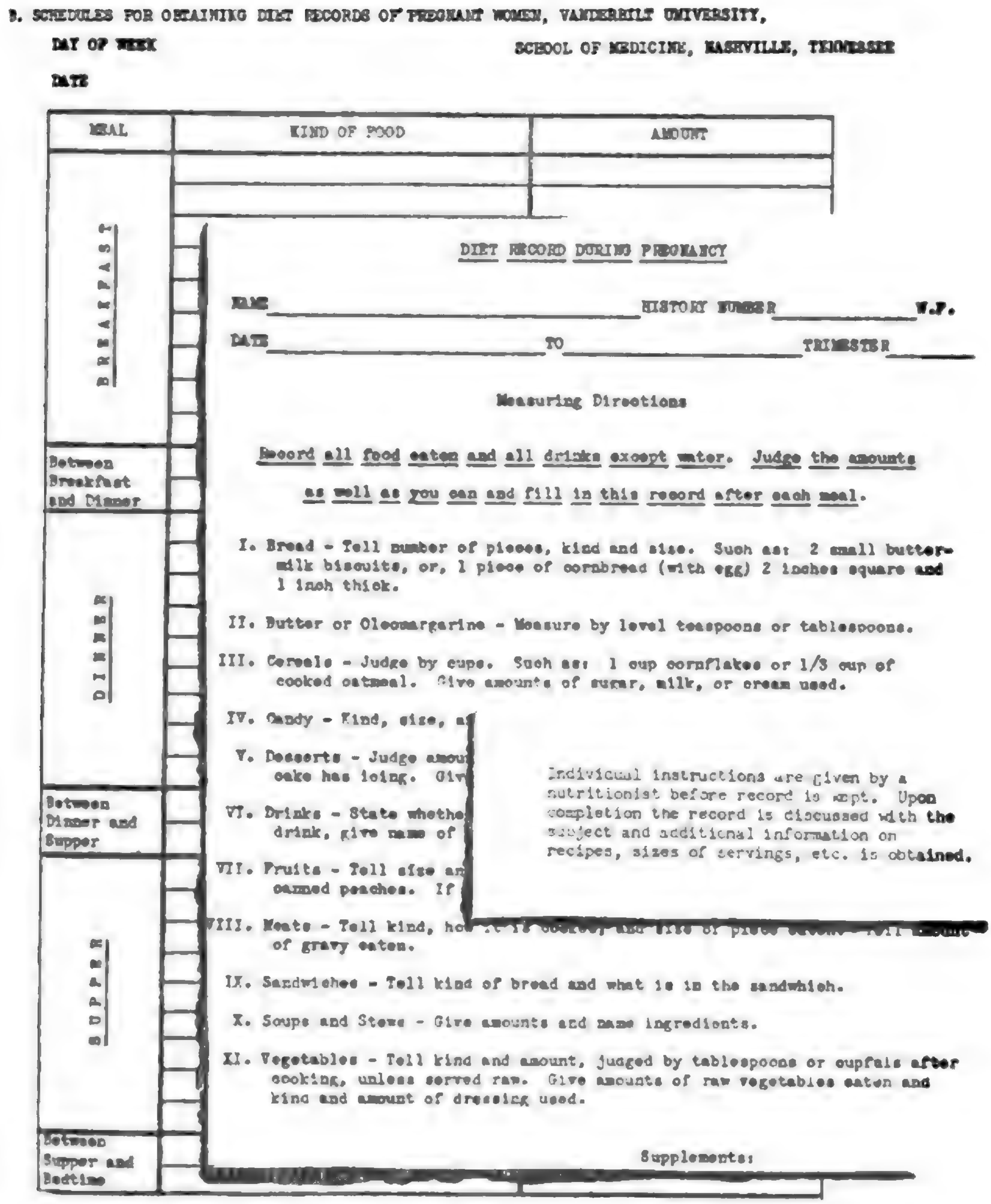
Hour arose this A.M. ____ Yesterday ____ Hr. to bed last night ____ Previous ____
School exercise periods: Yest. ________ Prev. ______
Outdoors: Yest. ________ Prev. ______
Work or chores: Yest. ________ Prev. ______
Reading or studying: Yest. ________ Prev. ______
Indoors: Movie, etc. Yest. ________ Prev. ______
Other: ________

USUAL ACTIVITIES

School clubs ______
Other clubs ______
Athletics ______
Dancing ______
Movies ______
Other ______

Food ______ Am't. ______

Vitamin Preparation:
Kind ______
Brand ______
Am't. ______



B. SCHEDULES FOR OBTAINING DIET RECORDS OF PREGNANT WOMEN, VANDERBILT UNIVERSITY, SCHOOL OF MEDICINE, NASHVILLE, TENNESSEE

DAY OF WEEK

DATE

MEAL	KIND OF FOOD	AMOUNT
BREAKFAST		
Between Breakfast and Dinner		
DINNER		
Between Dinner and Supper		
SUPPER		
Between Supper and Bedtime		

DIET RECORD DURING PREGNANCY

NAME ______________ HISTORY NUMBER ______________ W.P.

DATE ______________ TO ______________ TRIMESTER ______

Measuring Directions

Record all food eaten and all drinks except water. Judge the amounts as well as you can and fill in this record after each meal.

I. Bread - Tell number of pieces, kind and size. Such as: 2 small buttermilk biscuits, or, 1 piece of cornbread (with egg) 2 inches square and 1 inch thick.

II. Butter or Oleomargarine - Measure by level teaspoons or tablespoons.

III. Cereals - Judge by cups. Such as: 1 cup cornflakes or 1/3 cup of cooked oatmeal. Give amounts of sugar, milk, or cream used.

IV. Candy - Kind, size, a

V. Desserts - Judge amou
cake has icing. Giv

VI. Drinks - State whethe
drink, give name of

VII. Fruits - Tell size an
canned peaches. If

VIII. Meats - Tell kind, how it is cooked, and size of piece eaten. Tell amount of gravy eaten.

IX. Sandwiches - Tell kind of bread and what is in the sandwhich.

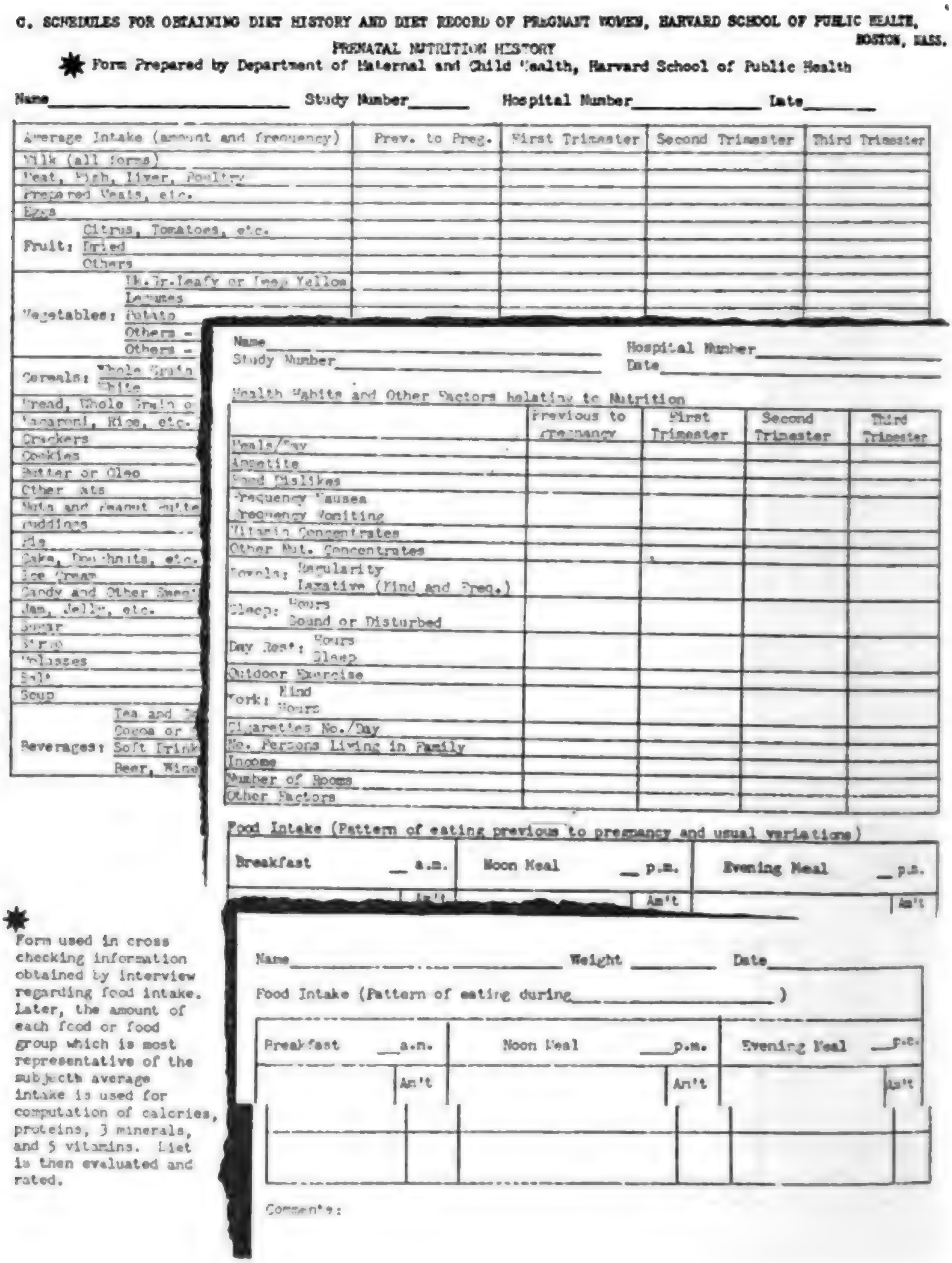
X. Soups and Stews - Give amounts and name ingredients.

XI. Vegetables - Tell kind and amount, judged by tablespoons or cupfuls after cooking, unless served raw. Give amounts of raw vegetables eaten and kind and amount of dressing used.

Supplements:

Individual instructions are given by a nutritionist before record is kept. Upon completion the record is discussed with the subject and additional information on recipes, sizes of servings, etc. is obtained.

Copyrig



C. SCHEDULES FOR OBTAINING DIET HISTORY AND DIET RECORD OF PREGNANT WOMEN, HARVARD SCHOOL OF PUBLIC HEALTH, BOSTON, MASS.

PRENATAL NUTRITION HISTORY

✱ Form Prepared by Department of Maternal and Child Health, Harvard School of Public Health

Name____________ Study Number______ Hospital Number________ Date______

Average Intake (amount and frequency)		Prev. to Preg.	First Trimester	Second Trimester	Third Trimester
Milk (all forms)					
Meat, Fish, Liver, Poultry					
Prepared Meats, etc.					
Eggs					
Fruit:	Citrus, Tomatoes, etc.				
	Dried				
	Others				
Vegetables:	Dk.Gr.Leafy or Deep Yellow				
	Legumes				
	Potato				
	Others -				
	Others -				
Cereals:	Whole Grain				
	White				
Bread, Whole Grain o					
Macaroni, Rice, etc.					
Crackers					
Cookies					
Butter or Oleo					
Other Fats					
Nuts and Peanut Butte					
Puddings					
Pie					
Cake, Doughnuts, etc.					
Ice Cream					
Candy and Other Swee					
Jam, Jelly, etc.					
Sugar					
Syrup					
Molasses					
Salt					
Soup					
Beverages:	Tea and				
	Cocoa or				
	Soft Drink				
	Beer, Wine				

Name____________ Hospital Number________
Study Number________ Date________

Health Habits and Other Factors Relating to Nutrition

		Previous to Pregnancy	First Trimester	Second Trimester	Third Trimester
Meals/Day					
Appetite					
Food Dislikes					
Frequency Nausea					
Frequency Vomiting					
Vitamin Concentrates					
Other Nut. Concentrates					
Bowels:	Regularity Laxative (Kind and Freq.)				
Sleep:	Hours Sound or Disturbed				
Day Rest:	Hours Sleep				
Outdoor Exercise					
Work:	Kind Hours				
Cigarettes No./Day					
No. Persons Living in Family					
Income					
Number of Rooms					
Other Factors					

Food Intake (Pattern of eating previous to pregnancy and usual variations)

Breakfast __ a.m.		Noon Meal __ p.m.		Evening Meal __ p.m.	
	Am't		Am't		Am't

Name____________ Weight ______ Date______

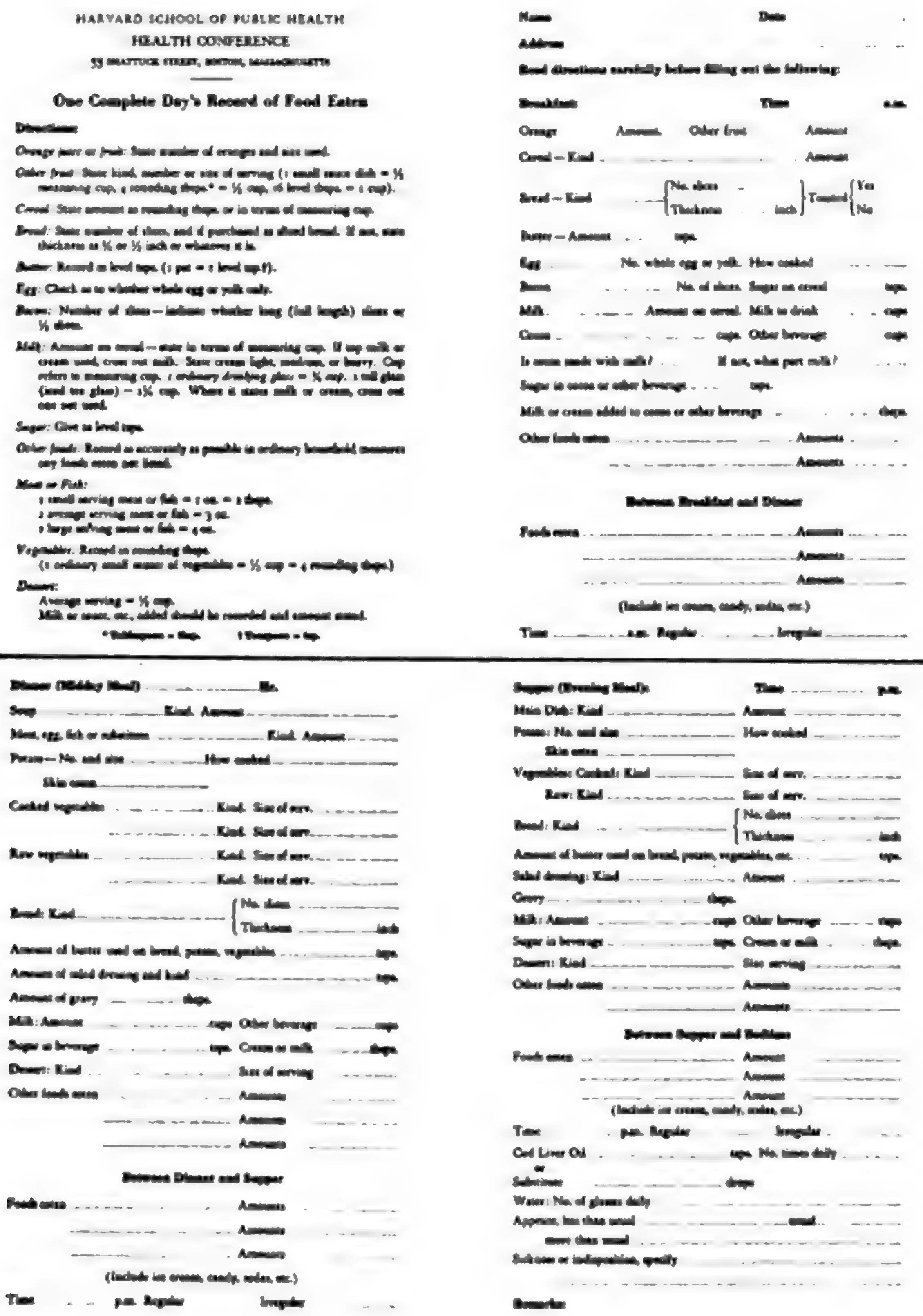
Food Intake (Pattern of eating during____________)

Breakfast __a.m.		Noon Meal __p.m.		Evening Meal __p.m.	
	Am't		Am't		Am't

Comments:

✱ Form used in cross checking information obtained by interview regarding food intake. Later, the amount of each food or food group which is most representative of the subjects average intake is used for computation of calories, proteins, 3 minerals, and 5 vitamins. Diet is then evaluated and rated.

1. C. (continued)



HARVARD SCHOOL OF PUBLIC HEALTH
HEALTH CONFERENCE
55 SHATTUCK STREET, BOSTON, MASSACHUSETTS

One Complete Day's Record of Food Eaten

Directions:

Orange juice or fruit: State number of oranges and size used.

Other fruit: State kind, number or size of serving (1 small sauce dish = ½ measuring cup, 4 rounding tbsps.* = ½ cup, 16 level tbsps. = 1 cup).

Cereal: State amount as rounding tbsps. or in terms of measuring cup.

Bread: State number of slices, and if purchased as sliced bread. If not, state thickness as ¼ or ½ inch or whatever it is.

Butter: Record as level tsps. (1 pat = 1 level tsp.†).

Egg: Check as to whether whole egg or yolk only.

Bacon: Number of slices — indicate whether long (full length) slices or ½ slices.

Milk: Amount on cereal — state in terms of measuring cup. If top milk or cream used, cross out milk. State cream light, medium, or heavy. Cup refers to measuring cup. *1 ordinary drinking glass* = ¾ *cup.* 1 tall glass (iced tea glass) = 1¼ cup. Where it states milk or cream, cross out one not used.

Sugar: Give as level tsps.

Other foods: Record as accurately as possible in ordinary household measures any foods eaten not listed.

Meat or Fish:
1 small serving meat or fish = 2 oz. = 3 tbsps.
1 average serving meat or fish = 3 oz.
1 large serving meat or fish = 4 oz.

Vegetables: Record as rounding tbsps.
(1 ordinary small sauce of vegetables = ½ cup = 4 rounding tbsps.)

Dessert:
Average serving = ½ cup.
Milk or sauce, etc., added should be recorded and amount stated.

* Tablespoon = tbsp. † Teaspoon = tsp.

Name ______ Date ______
Address ______
Read directions carefully before filling out the following:

Breakfast: Time ______ a.m.
Orange ______ Amount ______ Other fruit ______ Amount ______
Cereal — Kind ______ Amount ______
Bread — Kind ______ {No. slices ______ Thickness ______ inch} Toasted {Yes No}
Butter — Amount ______ tsps.
Egg ______ No. whole egg or yolk. How cooked ______
Bacon ______ No. of slices. Sugar on cereal ______ tsps.
Milk ______ Amount on cereal. Milk to drink ______ cups
Cream ______ cups. Other beverage ______ cups
Is cocoa made with milk? ______ If not, what part milk? ______
Sugar in cocoa or other beverage ______ tsps.
Milk or cream added to cocoa or other beverage ______ tbsps.
Other foods eaten ______ Amounts ______
______ Amounts ______

Between Breakfast and Dinner

Foods eaten ______ Amounts ______
______ Amounts ______
______ Amounts ______
(Include ice cream, candy, sodas, etc.)
Time ______ a.m. Regular ______ Irregular ______

Dinner (Midday Meal) ______ Hr.
Soup ______ Kind. Amount ______
Meat, egg, fish or substitute ______ Kind. Amount ______
Potato — No. and size ______ How cooked ______
Skin eaten ______
Cooked vegetables ______ Kind. Size of serv. ______
______ Kind. Size of serv. ______
Raw vegetables ______ Kind. Size of serv. ______
______ Kind. Size of serv. ______
Bread: Kind ______ {No. slices ______ Thickness ______ inch}
Amount of butter used on bread, potato, vegetables ______ tsps.
Amount of salad dressing and kind ______ tsps.
Amount of gravy ______ tbsps.
Milk: Amount ______ cups Other beverage ______ cups
Sugar in beverage ______ tsps. Cream or milk ______ tbsps.
Dessert: Kind ______ Size of serving ______
Other foods eaten ______ Amounts ______
______ Amounts ______
______ Amounts ______

Between Dinner and Supper

Foods eaten ______ Amounts ______
______ Amounts ______
______ Amounts ______
(Include ice cream, candy, sodas, etc.)
Time ______ p.m. Regular ______ Irregular ______

Supper (Evening Meal): Time ______ p.m.
Main Dish: Kind ______ Amount ______
Potato: No. and size ______ How cooked ______
Skin eaten ______
Vegetables: Cooked: Kind ______ Size of serv. ______
Raw: Kind ______ Size of serv. ______
Bread: Kind ______ {No. slices ______ Thickness ______ inch}
Amount of butter used on bread, potato, vegetables, etc. ______ tsps.
Salad dressing: Kind ______ Amount ______
Gravy ______ tbsps.
Milk: Amount ______ cups Other beverage ______ cups
Sugar in beverage ______ tsps. Cream or milk ______ tbsps.
Dessert: Kind ______ Size serving ______
Other foods eaten ______ Amounts ______
______ Amounts ______

Between Supper and Bedtime

Foods eaten ______ Amount ______
______ Amount ______
______ Amount ______
(Include ice cream, candy, sodas, etc.)
Time ______ p.m. Regular ______ Irregular ______
Cod Liver Oil ______ tsps. No. times daily ______
or
Substitute ______ drops
Water: No. of glasses daily ______
Appetite, less than usual ______ usual ______
more than usual ______
Sickness or indisposition, specify ______
______
Remarks:

II. FORMS FOR STUDYING THE FOOD INTAKE OF FAMILIES

A. EXCERPTS OF A FOOD RECORD SCHEDULE, BUR. OF HUMAN NUTRITION AND HOME ECONOMICS, U.S. DEPT. OF AGRICULTURE, WASHINGTON, D.C

A. Inventory of Food on Hand and Record of Food Brought into Home During Week

Food on hand.—The agent who visits your home will help you record what is on hand at the beginning of the week and again at the end. All staple foods stored in cabinet, cupboard, or pantry, or kept on dining room table or buffet and more perishable foods held in refrigerator, cold box, or cellar should be included. Any large supply of staple foods as potatoes, flour, home canned food, smoked meats, or frozen food in a storeroom, cellar or freezer locker separate from the kitchen, need not be entered on the inventory. Instead, supplies for current use can be entered when they are brought from storage into the kitchen.

Food brought in during the week.—List all foods brought into the kitchen before you put them away or use them. Include all food whether—Paid for or charged,
Carried or delivered,
Bought or from garden or storage (not inventory),
A gift or payment in food.

Before listing the food for a day, on the next free line in column 1, enter the day and date, as—1st day, October 14. If for any day no food is brought into the house, enter the day and date in column 1 and write "none" in column 2.

Inventory dates: Date of beginning inventory ____________ after ____________ meal
Date of closing inventory ____________ after ____________ meal

Food	Fresh, frozen, canned, dried, cured, ready-cooked	Bought, home-produced, other	Food on hand at beginning and food brought in day by day			Closing inventory		
			Number of units	Unit (Lb., qt.)	Price and unit of bought food	Number of units	Unit (Lb., qt.)	Price and unit of bought food
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
1 Fat in salvage can								
2					$			$ for

B. Recipe Sheet

Enter a recipe for each food mixture prepared at home that is—(1) on hand at time of beginning inventory, (2) on hand at time of closing inventory, or (3) eaten during the week of the record by a child in the 3rd - 6th grade.

1. Recipe: (a) Name ______________________ (b) Dates eaten during week ____________
2. For mixtures entered on either inventory, give proportion of total recipe on hand at time of:
   (a) Beginning inventory ________________ (b) Closing inventory ________________
3. For mixtures eaten by children in 3rd - 6th grades, give proportion of total recipe eaten during week by each child:
   Child No. 1 ______________ Child No. 2 ______________ Child No. 3 ______________

Foods List all foods used in recipe except seasonings, spices, flavorings; exclude water	Fresh, frozen, canned, dried, cured, ready-cooked	Bought, home-produced, other	Quantity		Food mixtures on inventories
			Number of units	Unit (Pt., cup, tbsp., tsp.)	Price and unit of bought food
(1)	(2)	(3)	(4)	(5)	(6)
					$ for

II. A. (continued)

C. Daily Menu from Family Food Supplies Day ______________ Date ________

Menu. Enter all foods and mixed dishes made from family food supplies that were eaten at meals or between meals by any member of the household or guests (1)	Quantity in household measure of each food eaten by children in 3rd - 6th grade Child No. ___ (2)	 Child No. ___ (3)	 Child No. ___ (4)
BREAKFAST			

NOON MEAL

EVENING MEAL

PACKED LUNCHES

BETWEEN-MEAL

(8) Enter kind

help (to

garbage;

D. Use of Cooking Water

1 a. Do you use the water in which any vegetables are cooked?
Yes ☐ No ☐
b. If Yes, which vegetables?
____
____
____

E. Identifying Information

1 School: Col.St. East Side
2 Assignment no. ____________
3 Agent ____________
4 State ____________
5 City ____________
6 Reviewer ____________
7 Dates covered ____________

DO NOT FILL

8 ____________
9 ____________
10 ____________
11 ____________
12 ____________

F. Daily Record of Persons Fed from Family Food Supplies

The agent who visits your home will help you fill in this page and enter the number of meals each person has from family food supplies day by day. Remember to tell the agent about packed lunches to be eaten at work, school, or picnics, and refreshments served to guests.

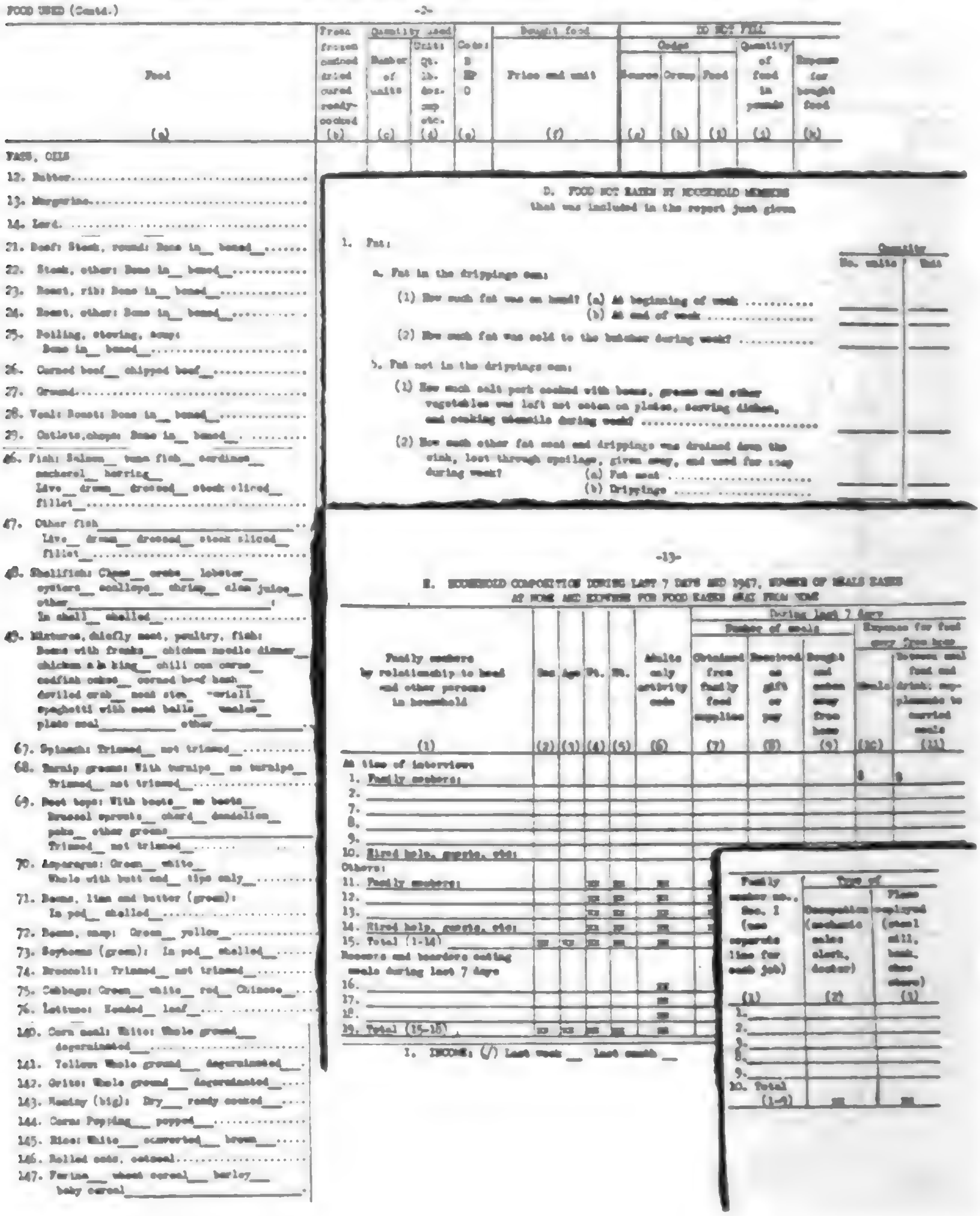
(1)	(2)	(3)	(4)	(5)	(6)	(7)																							
Persons (Give relation to head of family)	Age	Sex	Wt.	Hgt.	a. Adults--Activity code b. Children--Name of school	Check meals from family food supplies																							
						1st day			2nd day			3rd day			4th day			5th day			6th day			7th day			8th day		
						1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
1																													
2																													
3																													
4																													
5																													
6																													
12																													
Total																													

G. Record of Food Eaten Away from Home by Members of Family

Tell the agent, day by day, about meals eaten away from home by family members. Do not include meals carried from home food supplies. Also report cost of meals and snacks away from home.

Meals, supplements to meals, snacks	1st day	[illegible] day	3rd day	4th day	5th day	6th day	7th day	8th day
1 Number of meals: At work..................								
2 At school..................								
3 Other meals out..................								
4 Total (1-3): All..................								
5 Purchased..................								
6 Expense for purchased food: Meals (in item 5)	$	$	$	$	$	$	$	$
7 Supplements..................								
8 Between-meal soft drinks, candy, etc.								
9 Alcoholic drinks (at bar, etc.)..........								
10 Total (6-9)..................	$	$	$	$	$	$	$	$

B. EXCERPTS OF A FOOD LIST SCHEDULE, BUR. OF HUMAN NUTRITION AND HOME ECONOMICS, U.S. DEPT. OF AGRICULTURE, WASHINGTON, D.C.



FOOD USED (Contd.)

-2-

Food (a)	Fresh frozen canned dried cured ready-cooked (b)	Quantity used: Number of units (c)	Quantity used: Unit: qt. lb. doz. cup etc. (d)	Code: B HP G (e)	Bought food: Price and unit (f)	DO NOT FILL: Codes: Source (g)	Codes: Group (h)	Codes: Food (i)	Quantity of food in pounds (j)	Expense for bought food (k)
FATS, OILS										
12. Butter										
13. Margarine										
14. Lard										
21. Beef: Steak, round: Bone in__ boned__										
22. Steak, other: Bone in__ boned__										
23. Roast, rib: Bone in__ boned__										
24. Roast, other: Bone in__ boned__										
25. Boiling, stewing, soup: Bone in__ boned__										
26. Corned beef__ chipped beef__										
27. Ground										
28. Veal: Roast: Bone in__ boned__										
29. Cutlets, chops: Bone in__ boned__										
46. Fish: Salmon__ tuna fish__ sardines__ mackerel__ herring__ Live__ drawn__ dressed__ steak sliced__ fillet__										
47. Other fish______ Live__ drawn__ dressed__ steak sliced__ fillet__										
48. Shellfish: Clams__ crabs__ lobster__ oysters__ scallops__ shrimp__ clam juice__ other______; In shell__ shelled__										
49. Mixtures, chiefly meat, poultry, fish: Beans with franks__ chicken noodle dinner__ chicken a la king__ chili con carne__ codfish cakes__ corned beef hash__ deviled crab__ meat stew__ ravioli__ spaghetti with meat balls__ tamales__ plate meal______ other______										
67. Spinach: Trimmed__ not trimmed__										
68. Turnip greens: With turnips__ no turnips__ Trimmed__ not trimmed__										
69. Beet tops: With beets__ no beets__ Brussel sprouts__ chard__ dandelion__ poke__ other greens______ Trimmed__ not trimmed__										
70. Asparagus: Green__ white__ Whole with butt end__ tips only__										
71. Beans, lima and butter (green): In pod__ shelled__										
72. Beans, snap: Green__ yellow__										
73. Soybeans (green): In pod__ shelled__										
74. Broccoli: Trimmed__ not trimmed__										
75. Cabbage: Green__ white__ red__ Chinese__										
76. Lettuce: Headed__ leaf__										
140. Corn meal: White: Whole ground__ degerminated__										
141. Yellow: Whole ground__ degerminated__										
142. Grits: Whole ground__ degerminated__										
143. Hominy (big): Dry__ ready cooked__										
144. Corn: Popping__ popped__										
145. Rice: White__ converted__ brown__										
146. Rolled oats, oatmeal										
147. Farina__ wheat cereal__ barley__ baby cereal______										

D. FOOD NOT EATEN BY HOUSEHOLD MEMBERS
that was included in the report just given

	Quantity: No. units	Quantity: Unit
1. Fat:		
a. Fat in the drippings can:		
(1) How much fat was on hand? (a) At beginning of week		
(b) At end of week		
(2) How much fat was sold to the butcher during week?		
b. Fat not in the drippings can:		
(1) How much salt pork cooked with beans, greens and other vegetables was left not eaten on plates, serving dishes, and cooking utensils during week?		
(2) How much other fat meat and drippings was drained down the sink, lost through spoilage, given away, and used for soap during week? (a) Fat meat		
(b) Drippings		

-13-

E. HOUSEHOLD COMPOSITION DURING LAST 7 DAYS AND 1947, NUMBER OF MEALS EATEN AT HOME AND EXPENSE FOR FOOD EATEN AWAY FROM HOME

Family members by relationship to head and other persons in household (1)	Sex (2)	Age (3)	Wt. (4)	Ht. (5)	Adults only activity code (6)	During last 7 days: Number of meals: Obtained from family food supplies (7)	Received as gift or pay (8)	Bought and eaten away from home (9)	Expense for food away from home: Meals (10)	Between meal food and drink; supplements to carried meals (11)
At time of interview:										
1. Family members:									$	$
2.										
7.										
8.										
9.										
10. Hired help, guests, etc:										
Others:										
11. Family members:			xx	xx	xx					
12.			xx	xx	xx					
13.			xx	xx	xx					
14. Hired help, guests, etc:			xx	xx	xx					
15. Total (1-14)	xx	xx	xx	xx	xx					
Roomers and boarders eating meals during last 7 days										
16.					xx					
17.					xx					
18.					xx					
19. Total (15-18)	xx	xx	xx	xx	xx					

I. INCOME: (✓) Last week __ last month __

Family member no., Sec. E (use separate line for each job) (1)	Type of: Occupation (mechanic sales clerk, doctor) (2)	Type of: Place employed (steel mill, bank, shoe store) (3)
1.		
2.		
3.		
8.		
9.		
10. Total (1-9)	xx	xx

SECTION III

CHEMICAL TESTS AND THEIR INTERPRETATION

PAGE

Introduction 48
  Problems of interpretation of chemical tests 48
  Zones of nutriture in appraisal of nutritional status 49
  Available chemical tests; types; choice 49
Protein 50
  Methods: total serum protein, serum albumin, and globulin 51
  Normal values for serum proteins 51
  Findings in surveys 51
  Interpretation of data 52
Iron and Hemoglobin 52
  Hemoglobin methods 52
  Serum iron determination 53
  Differentiation of types of anemia 53
  Normal hemoglobin values 54
  Incidence of anemia 54
  Interpretation of hemoglobin and iron levels 54
Vitamins—General 55
  Types of tests available 55
  Factors influencing interpretation of findings 56
Vitamin A 56
  Methods: Vitamin A and carotene in blood 56
  Blood concentration: Vitamin A and carotene 57
    In normal persons 57
    In vitamin A deficiency 57
  Interpretation of findings 57
Vitamin B Complex 58
  Thiamine 58
    Tests for evaluation of thiamine nutrition 58
    Methods: Thiamine in urine 58
    Urinary excretion of thiamine 59
      Relationship to dietary intake 59
      Evaluation of 1-hr. and load test excretion 59
    Blood methods: Thiamine and cocarboxylase 60
    Lactate-pyruvate determinations 60
Riboflavin 61
  Methods: Riboflavin in urine 61
  Urinary excretion of riboflavin 61
    Relationship to dietary intake 61
    Evaluation of 1-hr. fasting excretion 61
    Test dose excretion: Interpretation 62
  Blood concentration: methods and findings 62
Niacin 63
  Methods: Urine and blood 63
  Urinary excretion of niacin derivatives 63
    One-hour fasting excretion: Interpretation 64
    Test dose excretion: Interpretation 64
  Niacin-tryptophane relationships 65

PAGE
Ascorbic Acid 65
  Methods: Blood and urine 65
  Blood concentration 66
    In plasma: Significance of findings 66
    In white cells: Interpretation 66
  Ascorbic acid and gum changes 67
  Urinary excretion 67
    One-hour fasting excretion 67
    Load tests: Oral and intravenous 67
  Interpretation of findings 68
Vitamin D and Calcium 68
  Determination of alkaline phosphatase 68
  Phosphatase values: Normal and in rickets 69
  Interpretation of high phosphatase values 69
  Blood calcium and phosphorus 69
Other Tests 70
  Routine Urinalysis 70
  Ketone bodies in urine and blood 70
  Chlorides in urine and blood 70
  Water and salt deficiency 70
Summary 71
Appendix: Recommended tests 80

INTRODUCTION

As information has accumulated concerning the chemical structure and function of essential nutritive factors, procedures have been developed for measuring the levels of these substances in bodily tissues and fluids and for detecting metabolic abnormalities which occur when the supply of these nutrients is insufficient. Many chemical and microbiological methods have been developed which are specific, accurate, and relatively easy to perform, but interpretation of the findings obtained with these methods, with respect to the adequacy of nutrition, remains fraught with difficulty. While it is generally agreed that there are important relationships between various levels of nutrition and growth, development, and the maintenance of normal health, quantitative definition of these relationships has not been accomplished. Data concerning human nutritional requirements are insufficient, knowledge of what constitutes optimal growth is lacking, and neither standards nor methods of precision for measuring normal health are available. Although considerable evidence indicates that there is a difference between the quantity of a nutrient which will protect against deficiency disease and illness, and the quantity necessary for the most efficient functioning of the body and the best possible health, knowledge of these amounts is largely unknown. Physiological and biochemical tests have not been sufficiently studied at various levels of nutrition for precise interpretation, nor have the concepts of adequate nutrition, potential deficiency, or optimal nutrition been clearly delineated. Unfortunately, these terms have been widely used in evaluating dietary, clinical, and biochemical findings in the appraisal of the nutritional status. This has led to differences of opinion as to the value of certain procedures and even to the condemnation of certain methods which, if properly applied and interpreted, might prove accurate and useful.

It is generally agreed that deficiency disease develops gradually and that several stages or degrees of deficiency may be recognized. At first there is a depletion of bodily stores of a nutrient, accompanied or followed by changes in the excretion of this substance or its metabolites and by diminution in the concentration of the nutrient in free or combined form in the blood. As deficiency continues there is impairment of function, and finally anatomical changes occur in the tissues and clinical signs of deficiency make their appearance.

Dann and Darby (1) have suggested that in the appraisal of nutritional status the following zones of nutriture might be recognized: (1) saturation ("the state in which the body is incapable of increasing its content of certain nutrients"); (2) unsaturation without functional impairment; (3) potential deficiency disease (decreased reserve functional capacity); (4) latent deficiency disease (vague symptoms responding to specific therapy); and (5) clinically manifest deficiency disease.

Chemical tests have been devised which may be applied in each of these zones of nutriture although in many instances they are few in number. Tests are available which will measure the degree of saturation of the body with a given nutrient (particularly of a vitamin) and there are numerous procedures by which excretion of a nutritive factor or its metabolites, or the level in the blood or bodily tissues may be determined. A few tests have been devised for measuring abnormalities in the function of essential nutrients. The reliability of available tests in the diagnosis of potential or latent deficiency disease has been seriously questioned. For evaluation in this borderline zone, new procedures must be developed and carefully controlled experiments conducted with present methods in an endeavor to correlate clinical, physiological, and biochemical findings. Nevertheless, much can be learned by the proper application of current knowledge in the appraisal of nutritional status.

The concentration of many essential nutrients in the blood, urine, or other bodily fluids reflects in a general way the recent dietary intake of these substances. However, concentration does not always bear a linear relationship to intake and many disturbing factors may influence findings in individual cases, particularly in the presence of illness. "Saturation", "load", or "tolerance" tests will determine the degree of saturation or depletion of the tissues with a given vitamin. The term saturation is an unfortunate one and should be used to denote maximal tissue concentration rather than optimal nutrition. In this sense, saturation suggests at least adequate nutrition and is a useful concept. Unsaturation may be compatible with undisturbed function, although an inability to withstand long periods of deprivation may be associated with this state. The question which must be answered is: at what tissue concentration does depletion become dangerous? As Johnson (2) has indicated, unsaturation is an indispensable and primary requisite in the diagnosis of deficiency, but corroborative evidence is necessary to complete the diagnosis. A given level of unsaturation may be considered indicative of deficiency only if clinical signs can be shown to occur at this level or if a brief period of deprivation will lead to manifest deficiency disease under controlled experimental conditions. Further difficulties in interpretation may be encountered in subjects, previously unsaturated, who have recently had access to nutrients sufficient to raise tissue concentration without restoring function or reversing pathologic changes.

Determination of the optimal level of a nutrient in the body will require long-term experiments. Repeated surveys of population groups who have been consuming diets extremely low in certain essential substances for many years may be of assistance in answering this problem, as well as the question of whether adaptation occurs to diminished nutrient supply.

The choice of chemical procedures for use in nutritional studies is dependent on the problems to be investigated. As Bessey and Lowry (3) have emphasized, reliable results will be obtained only if the strong and weak points of various methods are recognized and good judgment is used as to the circumstances under which tests are applied. In surveys, chemical procedures should be technically simple and inexpensive and should permit large numbers of samples to be run in a short period of time. Small specimens which may be procured with a minimum of patient inconvenience are desirable. Specificity and reliability are essential and, while accuracy should not be sacrificed, somewhat larger errors are permissible in methods applied to mass examination than in those used in testing individuals. In the interpretation of data, it should be appreciated that a single value does not represent normalcy but that there is a range of values for each physiological variant (4). Since these ranges have not been clearly defined for most of the essential nutrients, actual data obtained should be reported, preferably in the form of distribution curves. This will assist in establishing standards of normalcy and permit reevaluation in the future if and when new knowledge makes this desirable.

Micromethods such as those devised by Bessey and Lowry (5) are particularly useful in large-scale surveys. Fingertip blood is easily procured and determinations can be carried out with great rapidity. Macromethods such as those proposed by Johnson et al. (6) for field studies make use of rugged, simple equipment and can be applied in the study of population groups. The choice will depend upon the facilities available and the experience and training of the individuals participating in the survey. Findings of equal significance may be obtained with macro- or microprocedures. In most surveys, tests which may be applied to blood are preferable to those involving analysis of urine since blood may be obtained more readily in accurate amounts and less time is required.

Specific nutrients which have been studied in nutritional surveys with the use of biochemical methods include protein, iron, calcium, vitamin A, thiamine, riboflavin, niacin, ascorbic acid, vitamin D, and occasionally certain other substances. Each of these nutrients will be considered individually, existing methods of determination appraised, and the interpretation of findings discussed.

PROTEIN

In the evaluation of protein nutrition in population groups, the only chemical test which has been widely applied has been the determination of total serum or plasma protein, although the albumin and globulin fractions have also been measured in a few instances. In early studies, serum proteins were estimated by either the macro- or micro-Kjeldahl techniques. With the latter procedure, either titration or Nesslerization has been used in estimating total nitrogen. More recently, methods dependent on specific gravity have been devised. These have the advantage of speed and simplicity while retaining a high degree of accuracy. The falling drop method of Barbour and Hamilton (7) or of Kagan (8), the copper sulphate method of Phillips, Van Slyke et al. (9), and the micromethod of Lowry and Hunter (10), using the Linderstrom-Lang gradient tube, are all satisfactory. Atchley (11) found excellent agreement between the falling drop and copper sulphate methods and reasonably good checks between findings with these procedures and micro-Kjeldahl determinations.

The standard procedure for determining serum albumin has been separation from globulin by salt precipitation (12) or the sodium sulphate method (13) followed by determination of nitrogen by the Kjeldahl technique. Recently Lerner and Barnum (14) have proposed a method for the estimation of serum albumin and globulin, based on determination of the ultraviolet absorption of a diluted solution of serum proteins in a spectrophotometer. Total protein is measured simultaneously by one of the rapid specific gravity methods and serum albumin calculated from the combined data. This procedure may be applicable to surveys and appears worthy of critical testing.

The normal range of total serum protein in adults has been stated to be 6 to 8 gm. per cent; for serum albumin, 4.0 to 5.5 gm. per cent (15). The level of total serum protein is not as significant as that of albumin in evaluating protein nutrition, since it is influenced by the globulin fraction which may be increased in a number of pathologic states. In a recent study of 1100 subjects, Youmans et al. (16) found that 89 per cent of those with hypoalbuminemia had a normal concentration of total serum proteins.

Hypoproteinemia occurs when the protein in the diet is severely curtailed for long periods of time and in a number of diseases, including those involving the liver, certain types of renal pathology, and many conditions associated with loss of protein from the body.

The concentration of plasma proteins may remain constant for long periods of time in the presence of dietary protein deficiency. This may be due in part to the masking effect of hemoconcentration (17). If the volume of circulating plasma is determined, protein depletion may be detected at an earlier stage. The experiments of Madden, Whipple, and associates (18) have shown that plasma protein may reflect tissue stores. Elman and coworkers (19) have calculated that a reduction of 1 gm. in the total circulating plasma albumin indicates a loss of 30 gm. of body protein. A reduction in plasma albumin concentration from 4 to 3.5 gm. per 100 cc., in a person whose plasma volume was 3500 cc., would mean a reduction in total plasma albumin of 17 gm. and a tissue loss of about 510 gm. (20). If Elman's findings are correct, hypoproteinemia indicates protein deficiency of moderately advanced degree. Slight reduction in the concentration of total serum protein, or particularly of serum albumin, is significant in persons who are ambulatory and without signs of complicating disease.

In nutrition surveys in the United States (16) (21) hypoproteinemia has been an uncommon finding. In the study of a large population group in Tennessee, the incidence of hypoproteinemia was 3 per cent, of hypoalbuminemia 9 per cent (16). There was no demonstrable correlation between the level of serum albumin and the intake of calories, total protein, or animal protein. Dietary restrictions must apparently be more severe than those encountered in this study before a relationship between serum levels and protein intake can be demonstrated.

In a study of protein requirements, Hegsted and coworkers (22) found that total protein, plasma albumin, and plasma globulin tended to decrease when low protein, all-vegetable diets were fed at a level low enough to produce negative nitrogen balance. Kark, Bean, and their coworkers (23) in a study of the nutrition of troops in tropical areas found that there was reasonable correlation between the average intake of protein and the concentration in the serum. Indian troops, with a lower intake than Americans or Canadians, had lower levels of serum protein. Hypoproteinemia of mild degree was found to be common in certain famine areas (24) and in concentration camps (25) in World War II. Keys and coworkers (24) found a slight decrease in the plasma protein in 34 men maintained on a European type of famine diet for 6 months. A close correlation between "hunger" edema and levels of serum protein was not observed in these studies or in similar investigations elsewhere. This is not surprising in view of the multiple factors which affect edema formation. The complete story of the pathogenesis of nutritional edema has not been elucidated.

In the light of available evidence, it seems fair to interpret a low concentration of protein in the blood, particularly of the albumin fraction, as indicative of dietary protein deficiency if disease etiologically associated with low levels of serum protein can be eliminated.

IRON AND HEMOGLOBIN

One of the most widely used methods in appraisal of nutritional status is the determination of hemoglobin in the blood. The mean level of hemoglobin and the percentage of persons with values below the accepted range of normal have been considered good indices of the general health of the population. Many adverse environmental conditions, numerous pathologic states, particularly infections and diseases associated with blood loss, and several dietary factors, are important in the production of anemia. The quantity of hemoglobin in the blood has often been used as a measure of the prevalence of iron deficiency. This is not justifiable unless improvement can be demonstrated following therapy with iron. Iron deficiency is the most common dietary factor leading to anemia, but deficiency of protein, folic acid, and other less well defined nutrients such as the "extrinsic factor", may be of etiologic importance.

There are many methods for the determination of hemoglobin, none of which is ideal. Hemoglobin may be determined by dilution of blood with water (26) to which ammonia may be added to increase the stability of oxyhemoglobin (27). Bessey and Lowry (3) developed a micromethod requiring only 10 cu. mm. of whole blood in which, following dilution, hemoglobin is measured by light absorption in the photoelectric colorimeter.

Acid hematin procedures, although widely used, are largely unsatisfactory. It is difficult to obtain an accurate standard and color is affected by non-hemoglobin substances (27). The cyanmethemoglobin method is simple and accurate but the hazard of cyanide precludes its routine use (28). The alkaline hematin and carboxyhemoglobin procedures are a little less accurate but are satisfactory for most purposes

(28). The alkaline hematin method is preferable because it estimates carboxyhemoglobin, methemoglobin, and sulfhemoglobin, in addition to active hemoglobin. Regardless of the method chosen, photoelectric instruments are preferable to the older visual colorimeters for measurement of intensity of color. All instruments should be calibrated with one of several accurate methods such as 1) determination of oxygen capacity (29), 2) estimation of the iron content of blood or erythrocytes with the titanous chloride procedure (28), 3) the pyridine hemochromogen method with crystalline hemin as a standard (27), or 4) crystalline hemin in N/10 borate buffer at pH 9.4 (30).

Determination of hemoglobin indirectly from the specific gravity of whole blood and plasma, with the copper sulphate procedure of Phillips, Van Slyke et al. (9) has been used in many recent surveys. An accuracy of ±2 per cent is claimed for this method.

An anemia due to iron deficiency can usually be differentiated from anemia of other causation by determination of the volume of packed erythrocytes (hematocrit) and estimation of hemoglobin and the red cell count. From these data the size of the cells, or mean corpuscular volume and the mean corpuscular hemoglobin concentration can be calculated. Iron deficiency anemia is hypochromic and often microcytic. Mean corpuscular hemoglobin concentration falls below the normal of 34 ± 2 per cent, while mean corpuscular volume is often less than the normal of 87 ± 5 cu. micra. The anemia of folic acid deficiency, sprue, pernicious anemia, and possibly of protein deficiency, is macrocytic and the mean corpuscular volume is high.

Determination of the erythrocyte count with the usual counting chamber method is not feasible in surveys. Recently, however, Blum (31) has developed a photoelectric method for estimating the red cell count which may be applicable to mass studies. Hematocrit determination is relatively easy to perform. In future surveys, it should be possible to estimate mean corpuscular volume and mean corpuscular hemoglobin concentration. These data will assist in determining the etiology of anemia in a given population group. It is also suggested that blood smears should be made routinely in surveys. These can be saved and examined, when indicated, for size of cells or the presence of malaria parasites.

Another test for detecting iron deficiency is estimation of the level of serum iron. Both macro- (32a) and micromethods (32b) are available for this determination. The normal range for plasma iron is 0.05 to 0.180 mg. per cent (32b). Low serum iron is not pathognomonic of iron deficiency, however, since Wintrobe (27), Cartwright (32c), and others have observed a diminished concentration in infections, both acute and chronic.

The normal range of values for hemoglobin has not been definitely established and is variously stated according to the method used and the interpretation of the investigator. Hemoglobin should always be expressed in grams, not in per cent of normal, and standards should be based on distribution curves which are characteristic of each age and sex group. In this country, a commonly accepted standard of hemoglobin concentration in adults has been 14 ± 2 gm. per 100 cc. of blood for females, 16 ± 2 gm. for males (27). Recently, several reports of hemoglobin concentration in college women have been published (33) (34). Wintrobe (27) has suggested certain normal values for various age groups. Macy (35) found a range of 11 to 13 gm. in a group of children judged to be in excellent health. Milam and Muench (36) have reported distribution curves for hemoglobin as found in a survey in North Carolina. These studies, and those carried out in Britain which will be mentioned subsequently, should assist in standardizing criteria of normalcy and in recognizing variations in hemoglobin which may be compatible with good health.

A high incidence of anemia has been found in surveys in the United States, particularly in children and pregnant women of the lower income group (37) (38). A survey of hemoglobin levels in 16,000 persons in Great Britain in 1943 (39) was recently reported by the Medical Research Council, Committee on Hemoglobin Surveys. The Haldane-Gowers method, a visual colorimetric procedure, was adopted because of its wide use and simplicity. Dietary restrictions during the war did not cause deterioration of hemoglobin levels when comparison was made with previous data. Lower levels were found in women aged 40 to 49 than in other age groups and were considered to reflect blood loss and perhaps mild iron deficiency. In many instances hemoglobin concentration rose following iron therapy. The incidence of anemia in women was found to increase with the number of pregnancies. A similar relationship between pregnancy and anemia was reported in a survey in Newfoundland (40).

Several English workers (41) (42) reported a decrease in anemia in Britain during the war years and ascribed this to an increase in iron intake with the use of National whole wheat flour. Hemoglobin levels have been reported to be higher in the United States than in England, on lower intakes of iron (43). This seems to have been due to differences in methods and standards used for determination of hemoglobin (44). When the Haldane standard was re-calibrated, the levels of hemoglobin in Britain were found to be closer to those in the United States.

In the famine areas of Europe during World War II, anemia was a frequent finding and in a large percentage of cases it was macrocytic with a high color index (45) (46). Burger and coworkers (47) studied this type of anemia in Holland and found that liver, iron, and vitamins were without effect but that institution of a good diet brought about improvement. Wintrobe and Cartwright (48) found a high incidence of mild or moderate anemia, of macrocytic or normocytic type, in American military personnel who had been prisoners of the Japanese. Serum iron was slightly reduced in 55 per cent of the cases studied. The etiology of nutritional anemia not attributable to iron deficiency remains obscure, but it seems likely that deficiency of folic acid plays a role and that lack of protein, "extrinsic factor", or some poorly defined substance in the vitamin B complex may be significant.

Shank (32b), using a micromethod for determination of serum iron, has reported that when the level falls below 60 mcg. per cent, the administration of iron leads to a definite rise in hemoglobin; when the concentration of serum iron is greater than 60 mcg. per cent, therapy with iron is without effect on the hemoglobin level. Waldenstrom (48b) found iron deficiency a common problem in rural populations in Sweden. In one area, 22 per cent of the women examined had values for serum iron of less than

45 mcg. per cent. Determination of serum iron should prove to be a most useful procedure in the assessment of nutritional status.

Darby and coworkers (49) have used radioactive iron in a mass study of school children in Tennessee and showed the feasibility of this procedure in surveys. In adults, the absorption of radioactive iron was greater in persons with iron deficiency than in normal subjects. In children, the uptake of iron was correlated with the estimated yearly increase of body iron during growth. There was no correlation with estimated intake, hemoglobin level, economic status, or general nutritive state.

In general, it may be stated that determination of the concentration of hemoglobin in the blood is a valuable procedure in appraising nutritional status if the method used is carefully applied, if its limitations are sufficiently appreciated, and if findings are interpreted with full realization of the variability consistent with normal health.

VITAMINS

The procedures most commonly used for evaluation of nutritional status in regard to vitamins include measurement of the level in the blood during fasting or after giving a test dose of the vitamin and determination of the urinary excretion of the water-soluble vitamins. Excretion tests have included estimation of the output in one hour during fasting and "load" tests in which excretion is measured for a period of several hours after the oral or parenteral administration of a test dose. It is obviously impractical to determine excretion for 24-hour periods in surveys. The analysis of tissues obtained by biopsy has not been widely applied, although this procedure offers possibilities which merit further investigation.

Johnson and coworkers (50) concluded from a study of normal persons on relatively constant diets that fasting specimens were preferable to load tests and that random specimens of urine should not be used. When vitamin supplements were administered to one group of subjects, it was noted that the rate of excretion before breakfast was a more reliable index of intake in the previous few weeks than were vitamin load tests. These workers also reported that blood specimens might be collected at any time during the day without seriously influencing findings. The conclusions of Johnson et al are not necessarily valid for population groups on varied and inconstant diets.

The value of vitamin load tests in determining nutritional status has been the subject of much controversy. Opinions vary in regard to mode of administration, proper dosage, time of collecting specimens, and interpretation of results. Johnson, Contreras et al. (51) accomplished mathematical formulation of tolerance tests, both intravenous and oral, and suggested that collection of urine for one hour following an intravenous dose, and during the second hour after an oral dose (the periods of maximal excretion) might yield results comparable with those obtained from collections of 4 to 10 hours respectively. However, great individual variation might be an invalidating factor. These suggestions have not as yet been subjected to critical tests.

Berryman and coworkers (52) reported a relationship between the immediately preceding dietary intake of a given vitamin and the average urinary excretion of this nutrient during fasting, but cautioned against using the fasting urinary level alone to diagnose nutritional status. At extremes of intake there was a high correlation between the dietary level and the urinary excretion during fasting. There was no significant correlation between fasting urinary levels and the response to load tests. These authors emphasized that there was no assurance that all subjects in a group would have the same range of excretion on the same diet. Individual differences in absorption and variations in renal threshold affect results, and there is some evidence that the volume of urine excreted may be significant. In the collection of 1-hour specimens of urine, complete evacuation of the bladder is important. Lack of attention to this detail may invalidate findings. Accuracy will be greatly increased if specimens are collected over periods of 2 or 3 hours.

The repetition of load tests in normal persons at intervals of 2 to 3 weeks had no significant effect on the results of subsequent tests (fasting or load) according to Johnson and coworkers (50). These findings would probably not apply to studies of persons with deficiency disease. Any combination of thiamine, riboflavin, or ascorbic acid could be given without influencing the excretion of the other vitamins, and niacinamide had no effect on the output of these vitamins. Johnson et al. (2) concluded that oral load tests were preferable to intravenous, in spite of possible differences in absorption rate, because vitamin deficiencies due to poor absorption cannot be detected by injection, and it is difficult to maintain sterility in field studies. For the diagnosis of chemical deficiency, Johnson suggests that both a low excretion during fasting and a poor return after a test dose should be required, in view of the marked variation between individuals under similar dietary and environmental conditions. In interpreting findings, it should be remembered that in starvation tissues are being broken down and unexpectedly large amounts of certain nutrients may be excreted in the urine (53).

Sinclair (54) stated that, in his opinion, no analysis of urine in rapidly conducted surveys could provide useful information regarding the state of nutrition. This view seems unduly pessimistic. The findings of many workers suggest that the urinary excretion of water-soluble vitamins reflects bodily stores and hence is of some assistance in evaluating the nutritional status of population groups even though absolute figures to divide normal from deficiency states are lacking.

VITAMIN A

Chemical tests for the evaluation of vitamin A nutrition in surveys have been limited to determination of the concentration of vitamin A and carotene in the blood. Tests of vitamin A absorption have been used in studying the nutritional status of individuals and in investigating problems related to vitamin A metabolism but have not been applied in mass examinations. The same is true of estimation of the vitamin A content of liver tissue obtained by biopsy.

Procedures for the determination of vitamin A in blood have included a colorimetric method based on the Carr-Price reaction in which an unstable blue color is formed by the interaction of vitamin A and antimony trichloride, and an ultraviolet absorption method in which the light absorption of a solution of the vitamin is measured at 328 mu. with a spectrophotometer. Carotene has been determined by the solvent partition method and by the chromatographic technique. Chemical methods involving the Carr-Price reaction have been described by Kimble (55), Dann and Evelyn (56), Clausen and McCord (57), May et al. (58), and others. When these methods are used, the carotene content of the material must be simultaneously determined since it also forms a blue color with antimony trichloride. The intensity of the blue color is read at 660 mu. for vitamin A, 446 mu. for carotene, and the proper correction applied. Both the ultraviolet absorption procedure and the Carr-Price reaction have numerous drawbacks but are the only ones widely tested. Errors due to interfering substances can be serious. Bessey et al. (59) have described a microtechnique for the determination of vitamin A and carotene in blood which should be particularly useful in surveys. The method depends on saponification and extraction of vitamin A and carotene from 60 cu. mm. of serum, and measurement of the light absorption at 328 and 460 mu., followed by destruction of vitamin A and remeasurement at 328 mu. A detailed description of methods for determining vitamin A and carotene and a brief discussion of their application can be found in several recent publications (60) (61).

The normal range of values for vitamin A and carotene in the blood has not been completely determined. Among various groups of healthy individuals carotene has ranged from 50 to 400 mcg. per 100 cc. of blood (55, 62, 63, 64, 65). It has been suggested that the lower limit of normal be placed between 50 and 100 mcg. per cent for carotene, 40 and 75 I.U. for vitamin A (58, 59, 63, 64). In more recent studies the concentration of vitamin A has been expressed in micrograms, and Bessey (66) has suggested that the normal range is from 30 to 70 mcg. per 100 cc. of blood. Jolliffe (67) has considered 20 to 30 mcg. per cent as the lower limit of normal. In studies of hospitalized patients (68) and in a number of nutrition surveys (65) mean levels of both vitamin A and carotene in the blood have been lower than in normal healthy adults. In surveys in Tennessee and North Carolina (69) no correlation was found between vitamin A intake, plasma level, and clinical signs which were considered evidence of vitamin A deficiency. Krause and Pierce (70) found no difference in the concentration of vitamin A in the blood in children with and without folliculosis. In a survey in Newfoundland (71) where the intake of vitamin A was found to be low, the levels in the plasma were likewise low and the incidence of clinical signs atrributed to vitamin A deficiency was high.

In healthy adults Hsu (72) found the average concentration of vitamin A in the blood to be 56 I.U. per 100 cc. (range 30 to 104 I.U.); of carotene, 140 mcg. per 100 cc. (range 85 to 226 mcg.). In hospital patients without signs of vitamin A deficiency, the average value for vitamin A was 33 I.U. (range 0–132) and for carotene, 65 mcg. (range 0-197). In patients with clinical signs of vitamin A deficiency, averages were 6 I.U. for vitamin A (range 0–27) and 24 mcg. for carotene (range 0–141).

It seems apparent that there is a relationship between the amount of vitamin A and carotene in the blood and clinical evidence of vitamin A deficiency, but wide individual variations occur and a given level should be interpreted with caution. Moreover, it is well known that the concentration of vitamin A in the blood is decreased in many types of disease (73) (74). In normal experimental animals there is good correlation between vitamin A in the blood and liver reserves (73). Aron et al.

(75) have stated that levels of vitamin A and carotene in the blood are an expression of liver function. When the intake of vitamin A is reduced, blood levels decrease very slowly in adults, but in children reduction may be noted in 2 to 4 months. Yudkin (76) has pointed out that the quantity in the blood may be influenced by recent diet and may rise when signs of deficiency are still present. Aside from this, a normal level of vitamin A in the blood is not apt to occur in clinically manifest deficiency. It has been shown that supplements of vitamin A and carotene during pregnancy (77) will prevent the decrease which commonly occurs in the concentration of vitamin A in the blood.

In summary, a low level of vitamin A in the blood may mean vitamin A deficiency, decreased reserve stores, or the presence of some disease which affects vitamin A metabolism. Determination of vitamin A and carotene in the blood would appear to be more meaningful in group studies than in individual nutritional appraisal. Low levels suggest deficiency but should be correlated with other findings for definite diagnosis.

VITAMIN B COMPLEX

Chemical tests for three members of the vitamin B complex, thiamine, riboflavin, and niacin, have been extensively studied and applied to surveys. Excretion of other B vitamins such as pyridoxine, pantothenic acid, biotin, etc., have been included in certain investigations, but their importance in nutritional appraisal has not been demonstrated.

Thiamine.—The tests most frequently used in surveys in evaluating thiamine nutrition have been determination of the excretion in the urine for a one-hour period during fasting or for several hours following the administration of oral or parenteral test doses of this vitamin. Other tests have included measurement of thiamine in the blood or in tissues obtained by biopsy (78), determination of cocarboxylase in the blood (79), and estimation of blood pyruvic acid (80) (81) and of the blood lactate-pyruvate (82) (83) ratio during fasting, after glucose, and following exercise. Some of these procedures are more useful in appraising individual status than in evaluating the nutrition of population groups.

Methods for the determination of thiamine in urine have included: (1) the yeast fermentation procedure (84) which lacks specificity and gives higher values than other methods but has the advantage of measuring phosphorylated thiamine without hydrolysis (A technique for inactivating thiamine can be included); (2) a colorimetric method (85) using para-aminoacetophenone, the technique of which is laborious and which is not applicable to materials of very low thiamine content; and (3) the thiochrome method (86) which has been variously modified, has high sensitivity, and is applicable to material of low thiamine content but requires considerable time for completion. Perlzweig (87) has recently developed a modified thiochrome technique for rapid use in surveys. A disadvantage of the thiochrome technique is that urine contains non-thiamine fluorescent substances which may cause gross errors, particularly in urines of low thiamine content. In order to overcome this difficulty, Mason and Williams (88) suggested destruction of thiamine with sulfite to obtain a blank value, while Najjar and Ketron (89) measured fluorescence of a reagent blank and an alkali-treated aliquot and applied a correction factor. Mickelsen, Condiff, and Keys (90) eliminated interfering substances by control of acidity in the final extraction stage.

The urinary excretion of thiamine has been widely studied and more is known about the output of this vitamin at various levels of intake, and about the relationship between clinical and laboratory findings, than for any other member of the vitamin B complex. The urinary excretion of thiamine appears in a general way to be linearly related to thiamine intake. Mickelsen, Caster, and Keys (91) have shown, with statistical methods, that the excretion of thiamine is highly characteristic of the individual, as well as of the intake, and that variability in data becomes more marked as thiamine intake increases. They have suggested determination of both thiamine and pyramin, a pyrimidine-like component of the thiamine molecule which is excreted in the urine, in evaluation of thiamine nutrition when the intake of thiamine is unknown. At low levels of thiamine intake, the excretion of pyramin is still determinable, whereas the excretion of thiamine itself becomes zero. There is considerable disagreement in the literature in regard to the quantitative output of thiamine on low intakes and concerning the levels of excretion which may be considered indicative of normalcy and deficiency. This is particularly true in the interpretation of findings after test doses have been administered.

The excretion of thiamine has been shown to fall rapidly when the intake of this vitamin is lowered (92, 93, 94, 95, 96, 97, 98). However, Najjar and Holt (95) reported that the excretion may be at minimal levels for several months before signs of clinical deficiency appear. Michelsen et al. (91) stated that with an intake of about .07 mg. per day the thiamine excretion approached zero. Similar findings were obtained by Berryman (52). Hulse et al. (99) suggested that the urinary excretion of thiamine reflected changes in the concentration of freely diffusible and extracellular thiamine.

The amount of thiamine excreted in a 1-hour fasting specimen has been considered by many investigators (100, 50, 97, 101) to be useful in evaluating nutritional status, correlating well with the average daily intake. The exact quantity which is indicative of deficiency has been stated to be zero by Holt (100), 0.6 mcg. by Johnson and 4 mcg. by Papageorge and Lewis (101). Variation in interpretation is dependent on the definition of deficiency of the individual investigator. Correlation between the 1-hour fasting excretion and the 24-hour excretion has been reported by Melnick and Field (102), Papageorge and Lewis (101), and others. Holt (103) considers that the fasting 1-hour excretion is less liable to fluctuation due to changes of intake than the 24-hour excretion. The degree of deficiency cannot be detected by either the 1-hour fasting or the 24-hour excretion.

There is even more disagreement in regard to the interpretation of load tests. It is agreed that in persons on controlled intakes, the excretion following the administration of a test dose decreases as the intake of thiamine is reduced. Delineation of the level which may be diagnostic of deficiency has not been accomplished. Najjar and Holt (95) have found that thiamine excretion, after administration of 1 mg. of the vitamin intravenously, drops to less than 50 mcg. in 4 hours when symptoms of thiamine deficiency appear. Williams and Mason (93) (94) stated that an excretion of less than 100 mcg. with this test indicated moderate deficiency, less than 50 mcg., severe deficiency. Excretions of this low order occur only when the dietary intake is approximately 0.2 mg./1000 calories or less.

Johnson (2) used an oral load test in which 5 mg. of thiamine was administered and concluded that an output of less than 20 mcg. in 4 hours was subnormal. With this same test, Goldsmith and Sarett (104) found that 7 persons on normal diets excreted over 150 mcg. in 4 hours; 5 subjects on diets containing 0.2 to 0.3 mg. of vitamin B_1 per 1000 calories excreted less than 50 mcg. Melnick and Field (102) reported lower excretions in deficient than in normal subjects with load tests in which thiamine was given intramuscularly. Ruffin et al. (64) reported a significant difference in the excretion of thiamine in a 4-hour period by normal persons and patients with clinical findings of mild deficiency of the B vitamins, when 1 mg. was given intramuscularly. Oldham et al. (97) concluded that load test excretions gave a better idea of tissue stores than did the output in 1 hour during fasting or in a 24-hour period.

Of other tests available for assessing thiamine nutrition, estimation of the thiamine content of whole blood and of the erythrocytes and leukocytes merits further study. Foltz et al. (78) reported that the thiamine content of whole blood tends to correspond to the character of the diet but does not correlate well with urinary excretion. Greenberg and Rinehart (105) found the thiamine content of whole blood relatively static and not readily affected by changes in intake. Oldham et al. (97) reported a decrease in thiamine levels in the blood when the thiamine intake was 0.14 mg. per 1000 calories. Hennessy (106) emphasized that virtually all of the thiamine of blood is found in the cellular elements, so that a mere statement of findings without including an hematocrit determination is almost meaningless. It is preferable to know the thiamine content of the total cells, the hematocrit, and the white count. Erythrocytes contain about 8.6 mcg. and leukocytes, 70.6 mcg. per 100 cc. Studies of the thiamine content of the white cell platelet layer might be profitable.

The estimation of cocarboxylase in whole blood was considered by Goodhart and Sinclair (79) to be an unreliable method of detecting thiamine deficiency, while the level of thiamine in the plasma was thought to be more trustworthy. Hennessey (106), however, stated that there is almost no free thiamine in plasma. Hulse (99) reported a decrease in the yeast-stimulating activity of plasma in subjects on a diet low in thiamine. Further investigation is certainly needed before any of these tests can be applied in surveys.

Pyruvic acid determinations during fasting, after glucose, or after exercise are useful in evaluating thiamine nutrition, particularly in individuals. These methods require considerable care, are time-consuming, and are not readily applicable to surveys. Furthermore, many pathologic conditions other than thiamine deficiency are associated with a rise in pyruvic acid in the blood. Stotz and Bessey (82) suggested that the determination of both pyruvic and lactic acids with computation of the lactate-pyruvate ratio was of assistance in evaluating thiamine nutrition. Goldsmith (83) reported similar findings. Determination of blood pyruvate or of the lactate-pyruvate ratio after a standard exercise test may be informative of nutritional status and is worthy of further investigation (107) (83). Melnick (102) stated that urinary thiamine values were more sensitive indicators of changes in thiamine intake and of thiamine stores than were tests related to carbohydrate metabolism.

The thiamine content of muscle has been shown to decrease in thiamine deficiency (99). Muscle biopsies are not difficult to obtain and studies of the concentration of thiamine and other vitamins in such specimens should be undertaken.

Riboflavin.—Methods for the determination of riboflavin which are applicable to surveys include estimation of the quantity in the blood (serum and erythrocytes) and measurement of the urinary excretion for one hour during fasting and for several hours after the oral or parenteral administration of a test dose of riboflavin. Two types of procedures for the determination of riboflavin have been commonly employed, (1) microbiological and (2) fluorometric. In the microbiological method (108), *Lactobacillus casei* is the test organism and bacterial response is measured by titration of acid formed or turbidometrically. The fluorometric procedures have included those of Hodson and Norris (109) and of Conner and Straub (110) with numerous modifications. Ferrebee (111) introduced a "direct" method in which the adsorption procedure was omitted, and Najjar (112) proposed a fluorometric method applicable to biological materials. Bessey and Lowry (3) developed a micromethod in which riboflavin is determined in 15 cu. mm. of red cells by the rate of acid production by *Lactobacillus casei*. Fluorometric methods check well with the microbiological procedure if interfering fluorescent substances can be removed. This is at times difficult or impossible with biological materials such as urine. The direct method of Ferrebee (111) or Johnson's field method (6) are more rapid for mass studies but less accurate. The microbiological test is more specific and has a high degree of accuracy but requires considerable time and equipment.

In general, the amount of riboflavin excreted in the urine parallels the dietary intake until high levels are reached, at which time quantitative excretion is increased but the percentage of the intake excreted is little affected (113). Excretion may be dependent in part on the protein content of the diet (114) (115). Furthermore, Perlzweig (116) has shown that after 4 days of fasting, riboflavin excretion may be very high. Sure and Ford (117) reported a marked increase in the output of riboflavin in experimental animals when the diet was restricted in thiamine.

The excretion of riboflavin in 1 hour during fasting has been used by Najjar and Holt (100), Johnson (50), Kark and Bean et al. (23), and others, as an index of nutritional status. Kark and Bean et al. (23) showed a good correlation between the intake of riboflavin and the fasting 1-hour excretion of this vitamin. Brewer (113) found good correlation between the average excretion in 24 hours and in 1 hour during fasting. Similar findings were reported by Davis et al. (118) up to a certain level of intake. Hagedorn (119) reported fair agreement of the output in 1 hour with that in 24 hours. Johnson (2) has suggested that a fasting excretion of less than 20 mcg. per hour (with a rapid fluorometric method) is indicative of chemical deficiency. Cogswell et al. (120), in a study of subjects on diets containing 0.3 mg. of riboflavin daily, found an excretion averaging 16 mcg. in 1 hour. Holt (121) considered a level approaching zero evidence of deficiency. In infants on a diet free of riboflavin, he found a minimal 24-hour urinary excretion of 40 to 50 mcg. which would be about 2 mcg. per hour. Goldsmith and Sarett (104), using the microbiological method, found an excretion of 2 to 5 mcg. in one hour during fasting in 3 patients maintained for 5 to 6 weeks on a diet containing .5 mg. of riboflavin daily. The exact values reported by several groups of workers cannot be compared because of differences in the methods used.

Feder, Lewis, and Alden (122) reported that measurement of riboflavin in terms of concentration per cc. of urine gave a better index than did concentration per unit of time. Hathaway (123), however, found no relationship between riboflavin excretion and urinary volume. Kark (23) found a lower fasting excretion among Indians than among occidental troops. In the former, folliculosis, corneal invasion, and cheilosis were frequent findings. Hou and Dju (124) found riboflavin excretion (24-hour) lower in patients with glossitis, cheilosis, and eye signs of riboflavin deficiency than in normal persons. The amount of riboflavin excreted was usually proportional to the volume of urine and paralleled thiamine excretion.

The usefulness of load tests in evaluating riboflavin nutrition is the subject of much controversy. The size of the test dose has varied markedly and the usual differences of opinion have been expressed concerning the merits of oral or parenteral administration. Johnson (2) used a 5 mg. oral dose and considered an output of less than 200 mcg. in 4 hours evidence of unsaturation. Goldsmith and Sarett (104) in a study of 5 individuals maintained for 5 to 6 weeks on a diet containing 0.5 mg. riboflavin, found an excretion of 1.1 to 1.6 mg. in 4 hours after giving 5 mg. orally, while a small group of well-nourished persons excreted 1.5 to 3.9 mg. Davis et al. (118) noted a progressive increase in riboflavin excretion after an oral test dose of .02 mg. per kg. body weight as dietary levels were raised from .29 to .66 mg. of riboflavin per 1000 calories. No further increase occurred with higher intakes.

Brewer (113) found good correlation between the average excretion in 24 hours and the excretion for 4 hours after an oral dose of 3 mg. Correlation between the 1-hour fasting excretion and the test dose was not significant. Feder et al. (122) found a coefficient of correlation of .61 between the fasting excretion and the per cent of the test dose (.016 mg. per kg. intramuscularly) recovered in the urine. They concluded that saturation levels seldom gave more information than the fasting morning specimen. Hagedorn et al. (119) found that the retention of riboflavin supplements varied widely without apparent reason, and criticized the use of load tests as evidence of riboflavin deficiency.

Riboflavin in blood has been measured by the microbiological method using either macro- (125) (126) or micro- (3) procedures. Axelrod et al. (127) found no difference in the riboflavin content of the blood of normal persons and of patients with riboflavin deficiency. Hold (121) has recently studied infants on a riboflavin-free diet and found that riboflavin disappeared from the serum and that there was a marked reduction in the content of the erythrocytes and leukocytes. When the dietary intake of riboflavin was increased to .40–.45 mg. per day riboflavin was again present in the serum and the level in the erythrocytes and leukocytes returned to normal. Riboflavin was determined with the method of Birch, Shank, and Lowry (128) which requires special apparatus not readily available. Determination of riboflavin in blood, particularly in the cellular components, may prove useful in nutritional surveys and deserves further investigation.

Niacin.—Chemical tests for the appraisal of niacin nutrition have been numerous but far from satisfactory. Niacin is excreted in the urine in various forms, as N′ methylnicotinamide, small amounts of niacinamide and nicotinic acid, as nicotinuric acid, and in the form of a pyridone compound. Niacin and its amide may be determined by a microbiological procedure using *L. arabinosus* as the test organism (129) (130) or by chemical methods involving the König reaction, with cyanogen bromide and an aromatic amine, to form a colored compound (60).

Various procedures including hydrolysis with strong acid or alkali and removal of interfering substances, followed by application of the cyanogen bromide reaction (131) (132) have been used for measurement of niacin derivatives. The most important of these was thought at one time to be trigonelline but was later shown to be N′ methylnicotinamide. Procedures for the fluorometric determination of N′methylnicotinamide (F2) have been devised by Najjar and Wood (133), Huff and Perlzweig (134) and others. A simplified and sensitive method involving condensation of N′ methylnicotinamide with acetone, in alkaline solution, has recently been proposed by Huff and Perlzweig (135).

Recently Knox and Grossman (136) have isolated a pyridone from urine, N′ methyl-6-pyridone-3-carboxylamide, which seems to be the major excretory product of niacin (137). The method for determination of this pyridone is at present extremely difficult and simplification is essential for application to studies of human niacin nutrition. Perlzweig (138) has recently developed a procedure which may fill this need.

In the analysis of whole blood for niacin, results should be expressed in terms of hematocrit values or red cells since practically all the niacin is found in the erythrocytes, the amount in the plasma being negligible. The nicotinic acid of the cells is present almost entirely as pyridine nucleotides (139). Microbiologic assays employing *Hemophillus influenzae* and *parainfluenzae* are available for determining these metabolites and are simpler than chemical procedures. The fluorometric method employing condensation with acetone has recently been applied to the determination of pyridine nucleotides in cells and tissues (135). Carter and O'Brien (140) studied normal persons and patients with various diseases and concluded that the concentration of niacin in blood did not provide a useful nutritional guide. Axelrod et al. (141) and Kohn and Bernheim (142) reported that the determination of coenzyme I in the blood offered little diagnostic information in borderline cases of deficiency disease. These workers found an increase in coenzymes after niacin was administered. Youmans (143) stated that the level of coenzymes in blood failed to show close correlation with niacin deficiency. Vilter and associates (144) found that the blood level of codehydrogenase was lower in 3 pellagrins than in 4 normal persons.

Blood methods have not been used extensively in the investigation of niacin metabolism and there is a paucity of data concerning the levels of pyridine nucleotides in whole blood or in the cellular elements at various levels of nutrition. Further investigation along this line may be worthwhile despite the negative findings indicated above.

Numerous studies of the excretion of niacin derivatives in the urine have been carried out. There is little change in the urinary excretion of freely hydrolyzable derivatives of niacin with variations in diet, and only a slight decrease occurs in pellagra. Early reports, with the use of cyanogen bromide methods, showed that the urinary excretion of "trigonelline" was decreased in persons with niacin deficiency. A diminished output was found both in 24-hour specimens and in urine collected following the administration of a test dose of niacinamide (145) (146) (147).

In recent investigations the excretion of N′ methylnicotinamide has been measured in the fasting 1-hour urine and after the administration of a test dose of niacinamide. Many difficulties are involved in interpreting findings in these tests. The excretion of N′ methylnicotinamide accounts for only about 20 to 30 per cent of niacinamide given as a test dose (148) (149). Wide variations have been observed between individuals in the percentage of niacinamide excreted as methyl derivatives. The rate of methylation or the available methyl supply of the body may be important in this regard. However, determination of N′ methylnicotinamide appears to be the only procedure, applicable to urine, which is practical at the present time for use in surveys.

It is generally agreed that findings obtained should be interpreted with caution in evaluating niacin nutrition. Mickelsen and Erickson (150) found no difference in the excretion of subjects receiving .1 to 22 mg. of niacin per day over a period of 1 month. They concluded that determination of N′ methylnicotinamide in the 24-hour urine was of little value. Ruffin et al. (64) and Sargent et al. (151) reported that the urinary excretion of N′ methylnicotinamide correlated reasonably well with dietary and clinical evidence concerning bodily niacin stores. Holt and Najjar (152) reported the disappearance of F_2 in pellagra and its reappearance after vigorous therapy. They proposed the routine measurement of F_2 in surveys and suggested that if this substance was absent from the urine in the post-absorptive state, the niacin stores were low. Johnson (2) considered that an excretion of .03 mg. of N′ methylnicotinamide or less in 1 hour during fasting indicated unsaturation. However, it has been shown that normal persons occasionally excrete no N′ methylnicotinamide in the fasting specimen (151). Perlzweig (116) found little change in the excretion of N′ methylnicotinamide during a 4-day fast and Sargent (151) reported a high output in one man who fasted 16 days. Cayer and Cody (153) found an increased excretion of niacin derivatives in sprue associated with marked muscle wasting.

Following the administration of a test dose of niacinamide, there is a prompt rise in N′ methylnicotinamide excretion in normal subjects, reaching a maximum in 2 to 4 hours (100, 103, 154, 148). Occasionally a normal individual fails to show this increase (151). A high excretion of N′ methylnicotinamide may be more significant than a low excretion in the absence of prolonged fasting or wasting of muscles. Johnson (2) has suggested that an excretion of less than 0.5 mg. in 4 hours after administering 50 mg. of niacinamide orally indicates chemical deficiency. Cogswell et al. (120) showed that a decrease in N′ methylnicotinamide excretion after an intravenous dose of niacinamide occurred in 7 patients on a diet deficient in the B vitamins.

There are numerous reasons for the discrepancy of findings obtained by these and other investigators. Many different methods of analysis have been used and wide variations between individuals and in the same individual on different days have been demonstrated. As previously noted, there may be marked individual differences in the percentage of various metabolites of niacin which are excreted. Such differences may be due in part to the methylating ability of the organism. Furthermore, as Knox (137) has shown, N′ methylnicotinamide is not the major metabolite of niacin excreted in the urine of man.

A still more important factor leading to confusion in interpretation of data may be the relationship between tryptophane and niacin metabolism. Sarett and Goldsmith (155) and Perlzweig and coworkers (156) showed a marked increase in the excretion of N′ methylnicotinamide following the administration of tryptophane to persons on both normal and restricted diets. The increase appeared to be proportional to the amount of tryptophane given (157). Analysis of diets for tryptophane, as well as for niacin content, is essential if any correlation between dietary intake and urinary excretion is attempted. The whole field of niacin metabolism needs reevaluation. Studies at various levels of niacin and tryptophane intake, including investigation of patients with clinical pellagra, must be carried out. The urinary excretion of the pyridone compound of niacin (136) must be measured under various experimental conditions. It should not be too long before better tests are available and more accurate knowledge of the value of present tests can be ascertained.

One may conclude that, at present, the determination of N′ methylnicotinamide in the urine during fasting and after the administration of a test dose of niacinamide are worthwhile procedures in the assessment of nutritional status if conservative interpretation is applied to the findings.

ASCORBIC ACID

Ascorbic acid has been one of the most extensively studied of the essential nutrients and numerous tests have been proposed for the appraisal of ascorbic acid nutrition. In comparing the merits of various methods, evaluation would be much easier if some standardization of procedures had been attempted. Lack of agreement is particularly frequent in regard to load tests, which are almost as numerous as the investigators working in this field.

In the measurement of vitamin C in biological materials, the oxidation reduction properties of ascorbic acid are widely used as the fundamental reaction. The reducing capacity of acid extracts of the test material are measured by treatment with an oxidizing reagent, of which 2,6-dichlorophenolindophenol has been found the most satisfactory. Visual titration techniques (158, 159, 160, 161) and photometric methods (162, 163, 164, 165) based on this reagent have been applied in analyses of blood and urine. Visual titration may be inaccurate in extracts which contain water- or acid-soluble pigments, or reducing agents other than ascorbic acid which react rapidly with the dye and produce interference with the end point. Photometric methods partially overcome these difficulties. Many procedures for the removal of pigments and of interfering reducing substances have been suggested (60). Dehydroascorbic acid may be determined by the reaction with 2,4-dinitrophenylhydrazine to form an osazone which is converted to a red pigment upon treatment with sulfuric acid. This is the basis of the Roe and Oesterling (166) method for determining total ascorbic acid of whole blood and urine, and of the micromethod of Bessey, Lowry, and Brock (167) for estimation of ascorbic acid in blood. These methods are rapid and possess a high degree of specificity.

Tests for assessment of nutritional status include determination of the level of ascorbic acid in the plasma, whole blood, and white cell and platelet layer, and estimation of the urinary excretion during fasting and in a 24-hour period. In addition, a number of load tests have been proposed in which changes either in blood levels or in the urinary excretion of ascorbic acid are determined, for varying periods of time, after administering an oral or parenteral dose of ascorbic acid.

The level of ascorbic acid in the plasma during fasting corresponds in general with the dietary intake of this vitamin (23, 168, 169, 170, 171). Determination of this level has been a method commonly used in surveys because of the ease with which specimens can be obtained and the relative simplicity of the laboratory procedure. The significance of findings has been extremely controversial. Temporary fluctuations in plasma ascorbic acid are frequent (172), and there is a wide range of values at any given level of intake. Dodds and MacLeod (173) have recently reported mean values, together with ranges and standards of deviation, for 41 women receiving 32, 57, 82, and 107 mg. of vitamin C daily. These and similar findings should be useful in interpreting survey data. If recent intake has been liberal, 75 to 100 mg. daily, values of 1.0 to 1.4 mg. per 100 cc. will be obtained; if only 15 to 25 mg. has been included in the diet, values of 0.3 mg. or lower will be found (174).

Controversy has been chiefly concerned with the meaning of low levels of plasma ascorbic acid and determination of the point at which a deficiency state may be said to exist. Levels ranging from 0.3 to 0.7 mg. per 100 cc. of blood have been suggested as the lower limit of normal by various workers. If concentrations below these levels indicate an unsatisfactory state of nutrition, large segments of the population fall in this classification (38). In the opinion of several investigators, levels as low as 0.1 to 0.3 mg. per cent are not indicative of deficiency but merely reflect a low recent dietary intake or suggest that the body is not saturated with vitamin C. It has been emphasized that unsaturation is compatible with normal health. Ruffin et al. (64), Johnson (175), and others have reported plasma levels of zero in persons without clinical signs of scurvy. Johnson found that when healthy adults were placed on a diet containing no vitamin C, the serum ascorbic acid fell to zero in about 8 weeks. In Crandon, Lund, and Dill's experiment (176), plasma levels were zero for 13 weeks before clinical scurvy became evident, while leukocyte levels reached zero just prior to this. Lowry et al. (177) and Linghorne (178) noted a fall in the ascorbic acid of the serum to 0.2 mg. per cent on a daily intake of either 8 or 23 mg. of ascorbic acid. A definite relationship was shown to exist between the concentration in the serum and in the white cells. Serum levels of 0.4 mg. per cent or above were associated with concentrations in the leukocytes of more than 20 mg. per cent, while serum levels under 0.3 mg. per cent were associated with concentrations in the leukocytes of less than 20 mg. per cent. With a white cell value of one-half of normal, serum ascorbic was not zero but measured 0.1 to 0.4 mg. per cent. Realimentation studies indicated that the leukocytes appeared to be a valid index of total body concentration.

Bessey (3) found measurable differences in ascorbic acid in the serum of 3 groups of New York school children of different economic background. Farmer (169) found that in normal men, on a diet containing 0 to 10 mg. of vitamin C, the plasma ascorbic acid reached zero in 70 days. Serum levels below 0.3 mg. per cent have been considered indicative of chemical deficiency by Johnson (2). Dogramoci (179) found plasma levels of 0.1 to 0.3 mg. per cent (average .087) in 24 cases of scurvy. Vilter et al. (180) reported levels of 0.0 in 19 adults with scurvy and McMillan and Inglis (181) a mean of 0.05 mg. per cent in 22 subjects with this deficiency disease. Johnstone (182) found that a marked change in intake will be reflected by a change in the concentration in the blood during fasting in 1 to 2 weeks. Milam and Wilkins (183) showed that low plasma levels could be raised in a 6-week period by feeding an adequate diet.

Munks (184) in a study of vitamin C nutrition in pregnancy concluded that determination of ascorbic acid in the blood and urine was an unreliable index of nutritional status. Smith (185) stated that ascorbic acid in maternal blood was correlated with the dietary intake and with the level in the cord blood of the infant. In numerous disease states there is a decrease in the concentration of plasma ascorbic acid. This should be considered in evaluating results in studying certain weighted samples of the population.

In the majority of studies, little or no correlation has been demonstrated between the amount of ascorbic acid in the plasma or the degree of saturation of the tissues with vitamin C, and changes in the gums ascribed to deficiency of this nutrient (43, 37, 186, 187, 188, 189). In a few studies, the incidence of gingivitis appeared to be related to ascorbic acid intake or to plasma levels (180, 178, 191). In experimental deficiency, gum changes do not occur before other signs of scurvy (176)(169).

Although low concentrations of plasma ascorbic acid are found in the absence of clinical scurvy, this does not mean that such findings are of no significance. If the mean plasma level in a population group is low, it appears likely that the intake has been poor for long periods of time and that bodily stores have been depleted. Plasma levels of less than 0.3 mg. per cent are regarded by nearly all investigators as suggestive of chemical deficiency; many of those who have studied the problem most carefully consider that levels below 0.6 mg. per cent are indicative of an intake that is less than desirable.

The only tests of urinary excretion which can be used in surveys are those requiring brief periods for collection. The excretion in 1 hour during fasting or in several hours after a test dose of ascorbic acid may be determined. Close correlation has been reported by Johnson (50) between the average daily intake of ascorbic acid and the excretion in the urine before breakfast. The significance of this correlation has been questioned by Berryman (52). Interpretation of findings in the fasting urine in group surveys should be conservative.

Load tests for the assessment of ascorbic acid nutrition have employed varied dosage (either according to body weight or an arbitrary amount) administered orally or intravenously, and collection periods for urine or blood have ranged from 1 to 24 hours. In the evaluation of these tests, a certain percentage of the test dose excreted has been considered indicative of saturation, another percentage of deficiency. These percentages have been chosen by comparing findings in normal persons with those in patients with deficiency disease or by testing individuals under carefully controlled experimental conditions on various levels of intake. The numerous procedures suggested cannot be enumerated here (192)(143). A few recent studies will be mentioned which bear on the validity and interpretation of load tests.

Johnson, Darling, et al. (175) showed that the excretion of ascorbic acid for 3 and

6 hours after giving 1 gm. of the vitamin orally, definitely reflected the intake of subjects whose bodily stores were known to be very low, average, or high by virtue of subsistence on diets lacking, normal, or high in vitamin C. The level of serum ascorbic acid was distinctly different in the deficient and supplemented groups. In another study, Johnson and coworkers (2) suggested that an excretion of less than 3 mg. in 4 hours after an oral test dose of 500 mg. of ascorbic acid was indicative of chemical deficiency.

Farmer (169) studied normal men on a diet containing 0 to 10 mg. of vitamin C daily and conducted a saturation test employing an oral dose of 15 mg. per kg. of body weight, with measurement of ascorbic acid in the blood and urine every hour for 5 hours. This test was reported to be a reliable index of tissue depletion. Holland et al. (193), using the saturation test of Wright and coworkers (194) (1 gm. of ascorbic acid intravenously with determination of the 1½- and 5-hour urinary excretions), found a satisfactory correlation between the 5-hour excretion and the fasting level in the plasma in 85 per cent of 48 cases. Haines et al. (170) found that on daily intakes of 33 to 70 mg., the excretion in 24 hours after an oral test dose of 400 mg. corresponded with the intake. Youmans (143) pointed out that the findings with load tests paralleled findings in the plasma during fasting.

Kajdi et al. (195) concluded that a correlation existed between load tests and the clinical diagnosis of ascorbic acid deficiency or adequacy in infants. The test recommended by him consisted of measurement of plasma ascorbic acid 4 hours after the intramuscular injection of 200 mg. of ascorbic acid.

Berryman (52) concluded that correlation between the urinary excretion during fasting and the excretion following load tests appeared to be good at extremes of intake but less significant at intermediate levels. Kark et al. (23) in a study of troops in tropical areas found a correlation between the intake of ascorbic acid and the concentration in the serum and urinary excretion.

In various surveys, low concentrations of plasma ascorbic acid have been interpreted as indicative of a high incidence of deficiency of this vitamin. It might better be stated that the dietary intake had been low, that ascorbic acid reserves were reduced in a large sample of the population, and that chemical deficiency was presumably present in a certain percentage of this group. Investigation of the dietary history, measurement of ascorbic acid in the leukocytes, and the administration of load tests, can give additional information regarding the presence and severity of tissue depletion. Plasma levels mirror more closely the diet; white cell levels, the tissue stores.

VITAMIN D AND CALCIUM

In the appraisal of nutritional status in regard to calcium and vitamin D, only two procedures have been used in nutritional surveys: the determination of the level of calcium in the blood and the measurement of alkaline phosphatase in the serum. There are, at present, no chemical methods which permit estimation of vitamin D in biological materials of low potency (60). Studies of vitamin D in the blood are impractical and studies of excretion are lacking.

It has been recognized for a number of years that alkaline phosphatase increases in the serum in rickets and in a number of other diseases associated with abnormalities in the metabolism of bone. In 1933, Bodansky (196) proposed a method for determining alkaline phosphatase which has been used extensively. In 1946, Bessey et al. (197) developed a microprocedure using 3 to 20 cu. mm. of serum in which the amount of enzyme was measured with p-nitrophenyl phosphate as the substrate. There was only slight divergency of results with the two methods. The normal level of alkaline serum phosphatase is stated to be 3 to 12 Bodansky units in children up to the age of 12, and 3 to 5 units in adults. Klasmer (198) found values of 5.6 to 15 units in 320 healthy children between the ages of 6 months and 2½ years.

Alkaline serum phosphatase is elevated early in rickets and parallels the activity of the disease and the healing process. In mild rickets, the level may be 20 to 30 units, in severe rickets as high as 60 units (199). Determination of serum phosphatase is a reasonably reliable and accurate, although not specific, method of diagnosing early rickets and hypovitaminosis D. Other causes of an increase in phosphatase activity are uncommon at the age when rickets is prevalent and are easily detected (143). In adults and in children over 5 years, elevation of alkaline phosphatase in the serum is uncommon (200) and has been considered to be of doubtful significance. Recently Bessey (201) has found a slight increase in phosphatase in certain groups of children and has suggested that determination of this enzyme may be a useful tool, comparable to hemoglobin, in nutrition surveys. More data should be obtained in persons of all age and sex groups and under various conditions of metabolic activity.

Many diseases are of etiologic importance in variations in the concentration of phosphatase in older persons, and the likelihood of a relationship to vitamin D deficiency is not great. In China, a decided increase in phosphatase activity has been noted in osteomalacia. In a recent survey in Newfoundland, it was concluded that vitamin D deficiency was infrequent because few clinical signs of rickets were observed and low serum phosphatase values were obtained (71). The value of including phosphatase determinations in surveys other than those involving infants and young children remains to be determined.

Determination of the calcium and phosphorus content of blood has been used in the diagnosis of rickets and osteomalacia and in evaluating the severity of these conditions in individual subjects. Methods for these determinations are well known (202).

In nutrition surveys, particularly of adults, estimation of the calcium content of blood has not appeared to be worth while in the United States or Europe. Calcium deficiency of sufficient degree to produce changes in the blood is uncommon in these areas and interpretation of borderline findings in older children or in adults is extremely difficult. In studies of infants, or in certain adult populations in the Far East, estimation of the level of blood calcium may be a valuable part of survey techniques.

The normal concentration of calcium in the blood ranges from 9 to 11 mg. per cent in adults (203) and from 10 to 11 mg. per cent in children (204). Macy (202) found average values for calcium and phosphorus of 10.4 and 5.6 mg. per cent respectively in a group of children 5 to 12 years of age. If serum calcium falls to low levels, the clinical syndrome of tetany or osteomalacia occurs.

OTHER TESTS

Routine urinalysis—Ketone bodies in urine and blood—Chlorides in urine and blood:

In studies of population groups, routine urinalysis should be carried out whenever possible, including determination of specific gravity, qualitative tests for albumin and sugar, and microscopic examination of the sediment. The information obtained will assist in detecting medical defects which may be responsible for malnutrition and which may explain loss of weight, hypoproteinemia, anemia, and other findings in certain members of the group examined.

In certain surveys, it may be desirable to test for depletion of water and salt and to determine whether or not ketosis is present. An increase in blood ketones and ketonuria occurs in a number of disease states including complete and partial starvation. In childhood particularly, even short periods of inadequate carbohydrate intake may lead to ketosis (205). Problems of ketosis in relation to physical performance without food have been discussed by Keys (206). Analysis of urine for the presence of acetone bodies is a simple procedure which can readily be included in surveys of severely malnourished populations (6).

Water and salt deficiency are important problems in hot environments, especially in persons engaged in heavy labor. Dill (207) has shown that water expenditure may amount to 8 to 10 liters in 24 hours. A large part of the water loss is composed of sweat which also removes sodium and chloride from the body, and rapid dehydration may develop. Problems of electrolyte balance may be further complicated if vomiting or diarrhea occurs. Marriott (208) has emphasized that differentiation should be made between pure water depletion, pure salt depletion, and mixed depletion of both water and salt. Such differentiation is vitally important in evaluation of the water and electrolyte balance of individuals but is difficult to accomplish in surveys. Since combined depletion or pure salt deficiency are the common findings, the procedures of most value in surveys are the detection of hemoconcentration and the determination of plasma and urine chlorides.

Dehydration is suggested by a concentration of serum protein above 7.5 gm. per 100 cc. of blood (2) or by an increase in the volume of erythrocytes as measured by the hematocrit (205). The concentration of hemoglobin may also be increased.

In salt deficiency there is a diminution or absence of chlorides in the urine (208). A simple procedure for determination of urinary chloride is that of Fantus (208), or the method of Harvey has proved satisfactory (7). Johnson has suggested that an output of less than 0.2 gm. of sodium chloride per hour or a fasting serum chloride of less than 98 milliequivalents per liter is chemical evidence of salt deficiency. Talbott (209) considers that 100 milliequivalents per liter is the minimum normal concentration of serum chloride. In a study of persons with heat cramps, he found that the concentration of chloride in the urine was usually below 40 milliequivalents per liter. Marriott (208) has pointed out that the levels of chloride or sodium in the serum may not give accurate information as to the loss of sodium chloride from the body in states of mixed depletion where the loss of water is greater than that of salt. Detailed discussion of water and salt deficiency and of electrolyte balance may be found in several excellent reviews (205, 208, 209).

In a survey of troops in Southeast Asia, Kark et al. (23) found satisfactory levels of urinary and serum chlorides especially in units who salted their water or their atta. In certain hard-working units, however, where the importance of salt was either unrecognized or ignored, low serum chloride concentrations and low urinary chlorides were observed. Collapse and abdominal and muscular cramps were reported to have occurred in these units.

SUMMARY

Considerable progress has been made in the biochemical evaluation of nutritional status. Tests have been devised which are indicative of the previous dietary intake of nutrients, methods are available for estimating saturation or depletion of bodily stores of certain chemical substances, and there are a few tests which measure the metabolically active forms of dietary essentials and the abnormalities which occur in deficiency disease. Although exact criteria for the interpretation of findings in terms of deficiency, adequate, or optimal nutrition are lacking in most instances, chemical tests are a valuable part of survey techniques in obtaining a general picture of the nutritional level of population groups. Findings should be reported in terms of actual figures obtained or in the form of distribution curves rather than as deviations from a mean. This will permit reinterpretation of data when more accurate criteria for evaluation are available.

The use of micromethods has greatly facilitated the application of chemical tests to mass examination and should assist in solving many existing problems. New tests are needed and experiments under carefully controlled conditions with existing methods should yield valuable data. In the future, biochemical examination will undoubtedly be an integral part of all nutrition surveys.

BIBLIOGRAPHY

1. Dann, W. J. and Darby, W. J.: Appraisal of Nutritional Status (Nutriture) in Humans, with Especial Reference to Vitamin Deficiency Diseases. Physiol. Rev., *25:* 326–346, 1945.
2. Johnson, R. E., Sargent, F., Robinson, P. F., and Consolazio, F. C.: Assessment of Nutritional and Metabolic Condition in the Field; General and Clinical Aspects. War Medicine, *7:* 227–233, 1945.
3. Bessey, O. A. and Lowry, O. H.: Biochemical Methods in Nutritional Surveys. Am. J Pub. Health, *35:* 941–946, 1945.
4. Pett, L. B.: Errors in Applying Nutrient Allowances to Dietary Surveys or Food Policies. Canad. J. Pub. Health, *36:* 69–73, 1945.
5. Lowry, O. H. and Bessey, O. A.: Microchemical Methods for Nutritional Studies. Fed. Proc., *4:* 268–271, 1945.
6. Johnson, R. E.: Field Nutritional Laboratory. War Medicine, *7:* 222–226, 1945.
   Johnson, R. E., Sargent, F., Robinson, P. F., and Consolazio, F. C.: Estimation of Riboflavin, Thiamine, and N′-Methylnicotinamide—Rapid Field Methods. J. Ind. & Eng. Chem., Anal. Ed., *17:* 384–386, 1945.
7. Barbour, H. G. and Hamilton, W. F.: The Falling Drop Method for Determining Specific Gravity. J. Biol. Chem., *69:* 625, 1926.
8. Kagan, B. M.: A Simple Method for the Estimation of Total Protein Content of Plasma and Serum. J. Clin. Invest., *17:* 369–372, 1938.
9. Phillips, R. A., Van Slyke, D. D., Dole, V. P., Emerson, K., Jr., Hamilton, R. B., and Archibald, R. M.: Copper Sulfate Method for Measuring Specific Gravities of Whole Blood and Plasma. Bull. U. S. Army Med. Dept., *71:* 66–83, 1943.

10. Lowry, O. H. and Hunter, T. H.: Determination of Serum Protein Concentration with a Gradient Tube. J. Biol. Chem., *159:* 465–474, 1945.

11. Atchley, J., Bacon, R., Curran, G., and David, K.: Clinical Evaluation of Copper Sulfate Method for Measuring Specific Gravities of Whole Blood and Plasma. J. Lab. & Clin. Med., *30:* 830–838, 1945.

12. Robinson, H. W., Price, J. W., and Hogden, C. A.: Estimation of Albumin and Globulin in Blood Serum; A Study of Errors Involved in Filtration Procedure. J. Biol. Chem., *120:* 481–498, 1937.

    Separation of Fractions by Centrifugation with an Angle Centrifuge. Ibid., *126:* 207–212, 1938.

    Precipitation of Globulin at 25° by Sodium Sulfate. Ibid., *126:* 213–216, 1938.

13. Campbell, W. R. and Hanna, M. I.: Albumin, Globulin, and Fibrinogen of Serum and Plasma. J. Biol. Chem., *119:* 15–33, 1937.

14. Lerner, A. B. and Barnum, C. P.: A New, Rapid Method for Determination of Serum Albumin and Globulin by Ultraviolet Absorption. Arch. Biochem., *11:* 505–514, 1946.

15. Peters, J. P. and Eisenman, A. J.: Serum Protein in Diseases not Primarily Affecting the Cardiovascular System or the Kidneys. Am. J. Med. Sci., *186:* 808–833, 1933.

16. Youmans, J. B., Patton, E. W., Sutton, W. R., Kern, R., and Steinkamp, R.: Surveys of Nutrition of Populations; Protein Nutrition of a Rural Population in Middle Tennessee. Am. J. Pub. Health, *33:* 955–964, 1943.

17. Metcoff, J., Favour, C. B., and Stare, F. J.: Plasma Protein and Hemoglobin in the Protein-Deficient Rat; A Three-Dimensional Study. J. Clin. Invest., *24:* 82–91, 1945.

18. Madden, S. C. and Whipple, G. H.: Plasma Proteins: Their Source, Production, and Utilization. Physiol. Rev., *20:* 194–217, 1940.

19. Sachar, L. A., Horvitz, A., and Elman, P. J.: Studies on Hypoalbuminemia Produced by Protein-Deficient Diets; Hypoalbuminemia as a Quantitative Measure of Tissue Protein Depletion. J. Exper. Med., *75:* 243–259, 1942.

20. Stare, F. J. and Davidson, C. S.: Protein: Its Role in Human Nutrition; Introduction. J.A.M.A., *127:* 985–989, 1945.

21. Milam, D. F.: Plasma Protein Levels in Normal Individuals. J. Lab. & Clin. Med., *31:* 285–290, 1946.

22. Hegsted, D. M., Tsongas, A. G., Abbott, D. B., and Stare, F. J.: Protein Requirements of Adults. J. Lab. & Clin. Med., *31:* 261–284, 1946.

23. Kark, R. M., Aiton, H. F., Pease, E. D., Bean, W. B., Henderson, C. R., Johnson, R. E., and Richardson, L. M.: Tropical Deterioration and Nutrition; Clinical and Biochemical Observations on Troops. Medicine, *26:* 1–40, 1947.

24. Keys, A., Taylor, H. L., Mickelsen, O., and Henschel, A.: Famine Edema and the Mechanism of Its Formation. Science, *103:* 669–670, 1946.

25. Lipscomb, F. M.: Medical Aspects of Belsen Concentration Camp. Lancet, *2:* 313–315, 1945.

26. Evelyn, K. A.: A Stabilized Photoelectric Colorimeter with Light Filters. J. Biol. Chem., *115:* 63–75, 1936.

27. Wintrobe, M. M.: Clinical Hematology. Second Edition. Philadelphia, Pa. Lea and Febriger, 1946.

28. King, E. J., Gilchrist, M., and Delory, G. E.: Accuracy of Haemoglobin Methods. Lancet, *1:* 239–243, 1944.

29. Peters, J. P. and Van Slyke, D. D.: Quantitative Clinical Chemistry, Vol. 2. Baltimore. Williams & Wilkins Co., 1932.

30. Horecker, B. L.: Primary Standard of Colorimetric Determination of Hemoglobin. J. Lab. & Clin. Med., *31:* 589–594, 1946.

31. Blum, L. L.: Photoelectric Determination of Erythrocyte Count; Basic Principles and Technic. Am. J. Clin. Path., Tech. Sec., *9:* 85–93, 1945.

32a. Moore, C. V., Arrowsmith, W. R., Quilligan, J. J., Jr., and Read, J. T.: Studies in Iron Transportation and Metabolism. I. J. Clin. Invest., *16:* 613–626, 1937.

Moore, C. V., Doan, C. A., and Arrowsmith, W. R.: Studies in Iron Transportation and Metabolism. II. J. Clin. Invest., *16:* 627–648, 1937.

32b. Shank, R. E.: Microchemical Procedures and Their Use in the Investigation of Problems in Nutrition. A. P. H. A. Meeting, October 1947.

32c. Cartwright, G. E., Lauritsen, M. A., Jones, P. J., Merrill, J. M., and Wintrobe, M. M.: Anemia of Infection; Hyperferremia, Hypercupremia, and Alterations in Porphyrin Metabolism in Patients. J. Clin. Invest., *25:* 65–80, 1946.

33. Ohlson, M. A., Cederquist, D., Donelson, E. G., Leverton, R. M., Lewis, G. K., Himwich, W. A., and Reynolds, M. S.: Hemoglobin Concentrations, Red Cell Counts, and Erythrocyte Volumes of College Women of North Central States. Am. J. Physiol., *142:* 727–732, 1944.

34. Pedley, F. G.: Haemoglobin Concentration in College Women. Canad. Med. Assoc. J., *51:* 351–353, 1944.

35. Macy, Icie G.: Nutrition and Chemical Growth in Childhood, Vol. 2. Springfield, Illinois Charles C. Thomas, 1946.

36. Milam, D. F. and Muench, H.: Hemoglobin Levels in Specific Race, Age, and Sex Groups of a Normal North Carolina Population. J. Lab. & Clin. Med., *31:* 878–885, 1946.

37. Darby, W. J. and Milam, D. F.: Field Study of the Prevalence of Clinical Manifestations of Dietary Inadequacy. Am. J. Pub. Health, *35:* 1014–1021, 1945.

38. Inadequate Diets and Nutritional Deficiencies in the United States. Bull. No. 109, pp. 1–56, November 1943. Published by the National Research Council, National Academy of Sciences, Washington 25, D. C.

39. A Survey of Hemoglobin Levels in Great Britain in 1939. Nutrition Rev., *4:* 154, 1946.

40. Metcoff, J., Goldsmith, G. A., McQueeney, A. J., Dove, R. F., McDevitt, E., Dove, M. A., and Stare, F. J.: Nutritional Survey in Norris Point, Newfoundland. J. Lab. & Clin. Med., *30:* 475–487, 1945.

41. Fullerton, H. W., Mair, M. I., and Unsworth, P.: Survey of Haemoglobin Levels of Poor Classes in Aberdeen. Brit. Med. J., *2:* 373–374, 1944.

42. Davidson, L. S. P., Donaldson, G. M. M., Lindsay, S. T., and Roscoe, M. H.: Nutritional Iron Deficiency Anaemia in Wartime; Haemoglobin Levels of School Children and Pregnant Women in 1944 Compared with Levels in 1942 and 1943. Brit. Med. J. *2:* 333–334, 1944.

43. Milam, D. F. and Anderson, R. K.: Nutrition Survey of an Entire Rural County in North Carolina. South. Med. J., *37:* 597–605, 1944.

44. King, E. J., Gilchrist, M., and Matheson, A.: Haemoglobin Equivalent of B. S. I. Haldane Standard. Brit. Med. J., *1:* 250–252, 1944.

45. Nutritional Status of a Population Group in Madrid. Nutrition Rev., *1:* 231–233, 1943.

46. The Nutritional Situation in Internment Camps in France. Nutrition Rev., *2:* 205–207, 1944.

47. Burger, G. C. E., Sandstead, H. R., and Drummond, J.: Starvation in Western Holland. Lancet, *2:* 282–283, 1945.

48a. Cartwright, G. E. and Wintrobe, M. M.: Hematologic Survey of Repatriated American Military Personnel. J. Lab. & Clin. Med., *31:* 886–899, 1946.

48b. Waldenstrom, J.: Incidence of "Iron Deficiency" (Sideropenia) in Some Rural and Urban Populations. Acta Med. Scandinav., Supp., *170:* 252–279, 1946.

49. Darby, W. J., Hahn, P. F., Kaser, M. M., Steinkamp, R. C., Densen, P. M., and Cook, M. B.: Absorption of Radioactive Iron by Children 7–10 years of Age. J. Nutrition, *33:* 107–119, 1947.

50. Johnson, R. E., Henderson, C. R., Robinson, P. F., and Consolazio, F. C.: Comparative Merits of Fasting Specimens, Random Specimens, and Oral Loading Tests in Field Nutritional Surveys. J. Nutrition, *30:* 89–98, 1945.

51. Johnson, R. E., Contreras, L. A., Consolazio, F. C., and Robinson, P. F.: Comparison of Intravenous and Oral Vitamin Tolerance Tests. Am. J. Physiol., *144:* 58–68, 1945.

52. Berryman, G. H., Henderson, C. R., Wheeler, N. C., Cogswell, R. C., Jr., Spinella, J. R., Grundy, W. E., Johnson, H. W., Wood, M. E., Denko, C. W., Friedemann, T. E.,

Harris, S. C., Ivy, C. A., Youmans, J. B.: Effects in Young Men Consuming Restricted Quantities of B-Complex Vitamins and Protein, and Changes Associated with Supplementation. Am. J. Physiol., *148:* 618–647, 1947.

53. Perlzweig, W. A. and Sarett, H. P.: Unpublished data.
54. Sinclair, H. M.: Wartime Nutrition in England as a Public Health Problem. Am. J. Pub. Health, *34:* 828–832, 1944.
55. Kimble, M. S.: Photocolorimetric Determination of Vitamin A and Carotene in Human Plasma. J. Lab. & Clin. Med., *24:* 1055–1065, 1939.
56. Dann, W. J. and Evelyn, K. A.: Determination of Vitamin A with Photoelectric Colorimeter. Biochem. J., *32:* 1008–1017, 1938.
57. Clausen, S. W. and McCoord, A. B.: Carotinoids and Vitamin A of Blood. J. Pediat., *13:* 635–650, 1938.
58. May, C. D., Blackfan, K. D., McCreary, J. F., and Allen, F. H., Jr.: Clinical Studies of Vitamin A in Infants and in Children. Am. J. Dis. Child., *59:* 1167–1184, 1940.
59. Bessey, O. A., Lowry, O. H., Brock, M. J., and Lopez, J. A.: Determination of Vitamin A and Carotene in Small Quantities of Blood Serum. J. Biol. Chem., *166:* 177–188, 1946.
60. Biological Symposia, Vol. XII. Lancaster, Pa. The Jacques Cattell Press, 1947.
61. Association of Vitamin Chemists, Inc.: Methods of Vitamin Assay. New York. Interscience Publishers, 1947.
62. Abels, J. C., Gorham, A. T., Pack, G. T., and Rhoads, C. P.: Metabolic Studies in Patients with Cancer of the Gastro-Intestinal Tract; Plasma Vitamin A Levels in Patients with Malignant Neoplastic Disease, Particularly of the Gastro-Intestinal Tract. J. Clin. Invest., *20:* 749–764, 1941.
63. Youmans, J. B., Patton, E. W., Sutton, W. R., Stern, R., and Steinkamp, R.: Surveys of Nutrition of Populations; Vitamin A Nutrition of a Rural Population in Middle Tennessee Am. J. Pub. Health, *34:* 368–378, 1944.
64. Ruffin, J. M., Cayer, D., and Perlzweig, W. A.: The Relation Between the Clinical Picture of a Mild or Early Vitamin Deficiency and Laboratory Determinations of Vitamin Levels. Gastroenterology, *3:* 340–356, 1944.
65. Yarbrough, M. E. and Dann, W. J.: The Dark Adaptometer and Blood Vitamin A Measurements in a North Carolina Nutrition Survey. J. Nutrition, *22:* 597–607, 1941.
66. Bessey, O. A.: Personal communication, 1946.
67. Jolliffe, N.: Experiences in New York City Nutrition Clinics. A. P. H. A. Meeting, October 1947.
68. Harris, P. L., Hickman, K. C. D., Jensen, J. L., and Spies, T. D.: Survey of Blood Plasma Levels of Vitamin A, Carotene, Ascorbic Acid, and Tocopherols of Persons in an Area of Endemic Malnutrition. Am. J. Pub. Health, *36:* 155–160, 1946.
69. Anderson, R. K. and Milam, D. F.: Biomicroscopy of Eyes in Evaluation of Nutritional Status; Conjunctival Changes. J. Nutrition, *30:* 11–15, 1945.
70. Krause, R. F. and Pierce, H. B.: Blood Levels and Absorption of Vitamin A in Children with Keratosis Follicularis. J. Nutrition, *33:* 633–640, 1947.
71. Adamson, J. D., Jolliffe, N., Kruse, H. D., Lowry, O. H., Moore, P. E., Platt, B. S., Sebrell, W. H., Tice, J. W., Tisdall, F. F., Wilder, R. M., and Zamecnik, P. C.: Medical Survey of Nutrition in Newfoundland. Canad. Med. Assoc. J., *52:* 227–250, 1945.
72. Hsu, H. C.: Serum Carotinoids and Vitamin A in Chinese. Chinese Med. J., *6:* 239–243, 1943.
73. Popper, H.: Distribution of Vitamin A in Tissue as Vizualized by Fluorescence Microscopy. Physiol. Rev., *24:* 205–224, 1944.
74. Spector, S., McKhann, C. F., and Meserve, E. R.: Effects of Disease on Nutrition; Absorption, Storage, and Utilization of Vitamin A in the Presence of Disease. Am. J. Dis. Child., *66:* 376–395, 1943.
75. Aron, H. C. S., Craig, R. M., Farmer, C. J., Kendell, H. W., and Schwemlein, G. X.: Effect of Elevated Body Temperature on Plasma Vitamin A and Carotene. Proc. Soc. Exp. Biol. Med., *61:* 271–276, 1946.

76. Yudkin, J.: Nutritional Deficiency in the Pathogenesis of Disease. Brit. Med. J., *1:* 5, 1944.

77. Lewis, J. M., Bodansky, O., Lillienfeld, M. C. C., and Schneider, H.: Supplements of Vitamin A and of Carotene During Pregnancy; Their Effect on Levels of Vitamin A in Blood of Mother and of Newborn Infant. Am. J. Dis. Child., *73:* 143–150, 1947.

78. Foltz, E. E., Barborka, C. J., and Ivy, A. C.: Level of Vitamin B-Complex in Diet at Which Detectable Symptoms of Deficiency Occur in Man. Gastroenterology, *2:* 323–344, 1944.

79. Goodhart, R. S. and Sinclair, H. M.: The Estimation of Cocarboxylase (Vitamin B_1 Diphosphate Ester) in Blood. Biochem. J., *33:* 1099–1108, 1939.

— — and — —: Deficiency of Vitamin B_1 in Man as Determined by Blood Cocarboxylase. J. Biol. Chem., *132:* 11–21, 1940.

80. Bueding, E. and Wortis, H.: Stabilization and Determination of Pyruvic Acid in Blood. J. Biol. Chem., *133:* 585–591, 1940.

81. Friedemann, T. E., Haugen, G. E., and Kmieciak, T. C.: Pyruvic Acid; Level of Pyruvic and Lactic Acids, and Lactic-Pyruvic Ratio in Blood of Human Subjects. Effect of Food, Light, Muscular Activity and Anoxia at High Altitude. J. Biol. Chem., *157:* 673–689, 1945.

82. Stotz, E. and Bessey, O. A.: Blood Lactate-Pyruvate Relation and Its Use in Experimental Thiamine Deficiency in Pigeons. J. Biol. Chem., *143:* 625–631, 1942.

83. Goldsmith, G. A.: The Blood Lactate-Pyruvate Relationship in Various Physiologic and Pathologic States. Am. J. Med. Sci., *215:* 182–188, 1948.

84. Schultz, A. S., Atkin, L., and Frey, C. N.: Determination of Vitamin B_1 by Yeast Fermentation Method. Ind. Eng. Chem., Anal. Ed., *14:* 35–39, 1942.

85. Melnick, D. and Field, H., Jr.: Chemical Determination of Vitamin B_1. J. Biol. Chem., *127:* 505–514, 515–530, 531–540, 1939.

86. Hennessey, D. J. and Cerecedo, L. R.: Determination of Free and Phosphorylated Thiamin by a Modified Thiachrome Assay. J. Am. Chem. Soc., *61:* 179–183, 1939.

87. Perlzweig, W. A., Kamin, H., Gue, I., and Blalock, J. B.: Modification of Thiachrome Method for Rapid Determination of Thiamine in Urine. Arch. Biochem., *6:* 97–103, 1945.

88. Mason, H. L. and Williams, R. D.: Determination of Thiamine in Urine by the Thiachrome Method; Determination of the Blank. J. Biol. Chem., *146:* 589–594, 1942.

89. Najjar, V. A. and Ketron, K. C.: Improved Thiachrome Method for Determination of Thiamine in Urine. J. Biol. Chem., *152:* 579–584, 1944.

90. Mickelsen, O., Condiff, H., and Keys, A.: Determination of Thiamine in Urine by Means of Thiachrome Technique. J. Biol. Chem., *160:* 361–370, 1945.

91. Mickelsen, O., Caster, W. O., and Keys, A.: Statistical Evaluation of Thiamine and Pyramin Excretions of Normal Young Men on Controlled Intakes of Thiamine. J. Biol. Chem., *168:* 415–431, 1947.

92. Melnick, D.: Vitamin B_1 (Thiamine) Requirement of Man. J. Nutrition, *24:* 139–151, 1942.

93. Williams, R. D., Mason, H. L., and Wilder, R. M.: Minimum Daily Requirement of Thiamine of Man. J. Nutrition, *25:* 71–97, 1943.

Williams, R. D., Mason, H. L., Power, M. H., and Wilder, R. M.: Induced Thiamine (Vitamin B_1) Deficiency in Man; Relation of Depletion of Thiamine to Development of Biochemical Defect and of Polyneuropathy. Arch. Int. Med., *71:* 38–53, 1943.

94. Mason, H. L. and Williams, R. D.: Urinary Excretion of Thiamine as an Index of the Nutritional Level; Assessment of the Value of a Test Dose. J. Clin. Invest., *21:* 247–255, 1942.

95. Holt, L. E., Jr.: The Thiamine Requirement of Man. Fed. Proc., *3:* 171–178, 1944.

96. Denko, C. W., Grundy, W. E., Potter, J. W., and Berryman, G. H.: Excretion of B-Complex Vitamins in Urine and Feces of Seven Normal Adults. Arch. Biochem., *10:* 33–40, 1946.

97. Oldham, H. G., Davis, M. V., and Roberts, L. J.: Thiamine Excretions and Blood Levels of Young Women on Diets Containing Varying Levels of B Vitamins, With Some Observations on Niacin and Pantothenic Acid. J. Nutrition *32:* 163–180, 1946.

98. Gifft, H. H. and Hauck, H. M.: A Comparison of Four Methods for Studying the Urinary Excretion of Thiamine. J. Nutrition, *31:* 635–645, 1946.

99. Hulse, M. C., Weissman, N., Stotz, E., Clinton, M., and Ferrebee, J. W.: Subclinical

Vitamin Deficiency; Assay for Subclinical Thiamin Deficiency. Ann. Int. Med., *21:* 440-446, 1944.

100. Holt, L. E. Jr. and Najjar, V. A.: A Simple Method for the Laboratory Diagnosis of Subclinical Deficiencies of Thiamin, Riboflavin, and Nicotinic Acid. Bull. Johns Hopkins Hospital, *70:* 329, 1942.

101. Papageorge, E. and Lewis, G. T.: A Study of the Fasting-Hour Excretion of Thiamine in the Urine of Normal Subjects. J. Nutrition, *34:* 301–310, 1947.

102. Melnick, D. and Field, H., Jr.: Thiamine Clearance as an Index of Nutritional Status. J. Nutrition, *24:* 131–138, 1942.

103. Holt, L. E., Jr.: B Vitamins and Certain Problems They Present to the Practicing Physician. Penna. Med. J., *46:* 451–458, 1943.

104. Goldsmith, G. A. and Sarett, H. P.: Urinary Excretion of B Vitamins in Persons on Normal and Restricted Diets. Fed. Proc., *7:* 288, 1948.

105. Greenberg, L. D. and Rinehart, J. F.: Methods for Determination of Thiamine in Blood and Tissues, with Observations on Relative Contents. Proc. Soc. Exp. Biol. & Med., *59:* 9–13, 1945.

106. Hennessey, D. J.: Biological Symposia, Vol. XII, 86–120 B. Lancaster, Pa. The Jacques Cattell Press, 1947.

107. Keys, A., Henschel, A., Taylor, H. L., Michelsen, O., and Brozek J.: Experimental Studies on Man with Restricted Intake of B Vitamins. Am. J. Physiol., *144:* 5–42, 1945.

108. Snell, E. E. and Strong, F. M.: A Microbiological Assay for Riboflavin. Ind. Eng. Chem., Anal. Ed., *11:* 346–350, 1939.

109. Hodson, A. Z. and Norris, L. C.: Fluorimetric Method of Determining Riboflavin Content of Foodstuffs. J. Biol. Chem., *131:* 621–630, 1939.

110. Conner, R. T. and Straub, G. J.: Combined Determination of Riboflavin and Thiamin in Food Products. Ind. Eng. Chem., *13:* 385–388, 1941.

111. Ferrebee, J. W.: Urinary Excretion of Riboflavin; Fluorimetric Methods for Its Estimation. J. Clin. Invest., *19:* 251–256, 1940.

112. Najjar, V. A.: Fluorimetric Determination of Riboflavin in Urine and Other Biological Fluids. J. Biol. Chem., *141:* 355–364, 1941.

113. Brewer, W., Porter, T., Ingalls, R., and Ohlson, M. A.: The Urinary Excretion of Riboflavin by College Women. J. Nutrition, *32:* 583–596, 1946.

114. Sarett, H. P. and Perlzweig, W. A.: The Effect of Protein and B-Vitamin Levels of Diet Upon Tissue Content and Balance of Riboflavin and Nicotinic Acid in Rats. J. Nutrition, *25:* 173–183, 1943.

115. Sarett, H. P., Klein, J. R., and Perlzweig, W. A.: The Effect of the Level of Protein Intake Upon the Urinary Excretion of Riboflavin and Nicotinic Acid in Dogs and Rats. J. Nutrition *24:* 295–306, 1942.

116. Perlzweig, W. A., Huff, J. W., and Gue, I.: The Excretion of Thiamin, Riboflavin, and Nicotinic Acid by Fasting Men. Fed. Proc., *3:* 62, 1944.

117. Sure, B. and Ford, Z. W., Jr.: Vitamin Interrelationships; Thiamine and Riboflavin Interrelationships in Metabolism. J. Biol. Chem., *146:* 241–250, 1942.

118. Davis, M. V., Oldham, H. G., and Roberts, L. J.: Riboflavin Excretions of Young Women on Diets Containing Varying Levels of the B Vitamins. J. Nutrition, *32:* 143–161, 1947.

119. Hagedorn, D. R., Kyhos, E. D., Germek, O. A., and Sevringhaus, E. L.: Observation on Riboflavin Excretion by Adult Male. J. Nutrition, *29:* 179–189, 1945.

120. Cogswell, R. C., Berryman, G. H., Henderson, C. R., Denko, C. W., and Spinella, J. R.: Absence of Rapid Deterioration in Moderately Active Young Men on a Restricted Intake of B-Complex Vitamins and Protein. Am. J. Physiol., *147:* 39–48, 1946.

121. Holt, L. E., Jr.: Exhibit, New York Academy of Medicine, Postgraduate Fortnight. October 1947.

122. Feder, V. H., Lewis, G. T., and Alden, H. S.: Studies on Urinary Excretion of Riboflavin. J. Nutrition, *27:* 347–353, 1944.

123. Hathaway, M. L. and Lobb, D. E.: Comparison of Riboflavin Synthesis and Excretion in Human Subjects on Synthetic and Natural Diets. J. Nutrition, *32:* 9–18, 1946.

124. Hou, H. C. and Dju, M. Y.: Riboflavin Deficiency Among Chinese; Urinary Excretion of Riboflavin. Chinese Med. J., *61:* 121–130, 1942.
125. Strong, F. M., Feeney, R. E., Moore, B., and Parsons, H. T.: The Riboflavin Content of Blood and Urine. J. Biol. Chem., *137:* 363–372, 1941.
126. Bradford, E. A. M. and Coke, H.: The Microbiological Determination of Riboflavin in Blood. Biochem. J., *39:* 379–385, 1945.
127. Axelrod, A. F., Spies, T. D., and Elvehjem, C. A.: The Riboflavin Content of Blood and Muscle in Normal and in Malnourished Humans. Proc. Soc. Exp. Biol. Med., *46:* 146–149, 1941.
128. Birch, C. L., Shank, R. E., and Lowry, O. H.: To be published.
129. Snell, E. E. and Wright, L. D.: A Microbiological Method for the Determination of Nicotinic Acid. J. Biol. Chem., *139:* 675–686, 1941.
130. Krehl, W. A., Strong, F. M., and Elvehjem, C. A.: Determination of Nicotinic Acid. Modifications in the Microbiological Method. Ind. Eng. Chem., Anal. Ed., *15:* 471–475, 1943.
131. Perlzweig, W. A., Levy, E. D., and Sarett, H. P.: Nicotinic Acid Derivatives in Human Urine and Their Determination. J. Biol. Chem., *136:* 729–745, 1940.
132. Melnick, D. and Field, H., Jr.: Determination of Nicotinic Acid in Biological Materials by Means of Photoelectric Colorimetry. J. Biol. Chem., *134:* 1–16, 1940.
Ibid., *135:* 53, 1940.
133. Najjar, V. A. and Wood, R. W.: The Presence of Hitherto Unrecognized Nicotinic Acid Derivative in Human Urine. Proc. Soc. Exp. Biol. Med., *44:* 386–390, 1940.
134. Huff, J. W. and Perlzweig, W. A.: Methylnicotinamide, Metabolite of Nicotinic Acid in Urine. J. Biol. Chem., *150:* 483–484, 1943.
135. Huff, J. W., Perlzweig, W. A., and Tilden, M. W.: A Simple Method for the Determination of N′-Methylnicotinamide in Urine. Fed. Proc. *4:* 92–93, 1945.
136. Knox, W. E. and Grossman, W. I.: A New Metabolite of Nicotinamide. J. Biol. Chem., *166:* 391–392, 1946.
137. Knox, W. E.: Identification of New Metabolites of Nicotinic Acid. A. A. A. S. Conference. New London, New Hampshire. 1947.
138. Rosen, F., Perlzweig, W. A., and Handler, P.: A Fluorometric Assay for N′Methyl-6-Pyridone-3-Carboxylamide. Fed. Proc. *7:* 181, 1948.
139. Klein, J. R., Perlzweig, W. A., and Handler, P.: The Determination of Nicotinic Acid in Blood Cells and Plasma. J. Biol. Chem., *145:* 27–34, 1942.
140. Carter, C. W. and O'Brien, J. R. P.: The Nicotinic Acid Content of Blood in Health and Disease. Quart. J. Med., *14:* 197–205, 1945.
141. Axelrod, A. E., Gordon, E. S., and Elvehjem, C. A.: The Relationship of Dietary Intake of Nicotinic Acid to Coenzyme I Content of Blood. Am. J. Med. Sci., *199:* 697–705, 1940.
142. Kohn, H. I. and Bernheim, F.: Blood V-Factor (Coenzyme) in Normal and Pathological Subjects. J. Clin. Invest., *18:* 585–591, 1939.
143. Youmans, J. B. and Patton, E. W.: Laboratory Diagnosis of Nutritional Deficiencies. Clinics, *1:* 303–345, 1942.
144. Vilter, R. W., Vilter, S. P., and Spies, T. D.: The Relationship Between Nicotinic Acid and Codehydrogenase (Cozymase) in Blood of Pellagrins and Normal Persons. J. A. M. A., *112:* 420–422, 1939.
145. Perlzweig, W. A., Sarett, H. P., and Margolis, L. H.: Studies in Nicotinic Acid Metabolism; A Test for Nicotinic Acid Deficiency in Man. J. A. M. A., *118:* 28–30, 1942.
146. Goldsmith, G. A.: Urinary Excretion of Nicotinic Acid and Its Derivatives. Arch. Int. Med., *73:* 410–414, 1944.
147. Field, H., Jr., Melnick, D., Robinson, W. D., and Wilkinson, C. F., Jr.: Studies on Chemical Diagnosis of Pellagra (Nicotinic Acid Deficiency). J. Clin. Invest., *20:* 379–386, 1941.
148. Coulson, R. A., Ellinger, P., and Smart, G. A.: Urinary Elimination of Nicotinamide Methochloride in Subjects with Normal Gums and with Acute and Chronic Gingivitis. Brit. Med. J., *1:* 6–8, 1945.
149. Sarett, H. P., Huff, J. W., and Perlzweig, W. A.: Studies in Nicotinic Acid Metabolism; The Fate of Nicotinic Acid in Man. J. Nutrition, *23:* 23–34, 1942.

150. Mickelsen, O. and Erickson, L. L.: Iron (Fluorescent Substance) of Normal Men on Different Levels of Niacin Intake. Proc. Soc. Exp. Biol. Med., *58:* 33–36, 1945.

151. Sargent, F., Robinson, P. F., and Johnson, R. E.: F_1 and F_2 of Najjar and Holt in Urine of Normal Young Men. J. Clin. Invest., *23:* 714–719, 1944.

152. Najjar, V. A. and Holt, L. E. Jr.: Excretion of Specific Fluorescent Substances in Urine in Pellagra. Science, *93:* 20–21, 1941.

Najjar, V. A.: Laboratory Diagnosis of Nicotinic Acid Deficiency; Improved Procedure for Determination of F_2 (N-Methyl Nicotinamide Derivative) in Urine. Bull. Johns Hopkins Hospital, *74:* 392–399, 1944.

Najjar, V. A., Stein, H. J., Holt, L. E., Jr., and Kabler, C. V.: The Excretion of Specific Fluorescent Substances in Urine in Experimental Nicotinic Acid Deficiency. J. Clin. Invest., *21:* 263–267, 1942.

153. Cayer, D. and Cody, S.: The Nutritional Status of Patients with Peptic Ulcer as Measured by Vitamin Levels in the Blood and Urine. Gastroenterology, *9:* 54–63, 1947.

154. Holt, L. E., Jr. and Najjar, V. A.: A Simple Method for the Laboratory Diagnosis of Subclinical Deficiencies of Thiamin, Riboflavin, and Nicotinic Acid. Fed. Proc., *1:* 117, 1942; Journal-Lancet, *63:* 366, 1943.

155. Sarett, H. P. and Goldsmith, G. A.: Effect of Tryptophane on Excretion of Nicotinic Acid Derivatives in Humans. J. Biol. Chem., *167:* 293–294, 1947.

156. Perlzweig, W. A., Rosen, F., Levitas, N., and Robinson, J.: Excretion of Nicotinic Acid Derivatives After Ingestion of Tryptophane by Man. J. Biol. Chem., *167:* 511–514, 1947.

157. Sarett, H. P. and Goldsmith, G. A.: Further Observations on the Relationship of Tryptophane and Nicotinic Acid Metabolism in Humans. Fed. Proc., *6:* 288, 1947.

158. Tillmans, J., Hirsch, P., and Vaubel, R.: Reducing Capacity of Plant Foods in Relation to Vitamin C. 6. Preparation of Pure Reducing Substance from Rose Hips and Its Identity with Vitamin C. Ztschr. Untersuch. Lebensmitt., *65:* 145–167, 1933.

159. Harris, L. J. and Ray, S. N.: Specificity of Hexuronic (Ascorbic) Acid as an Antiscorbutic Factor. Biochem. J., *27:* 580–589, 1933.

160. Bessey, O. A. and King, C. G.: The Distribution of Vitamin C in Plant and Animal Tissues, and Its Determination. J. Biol. Chem., *103:* 687–698, 1933.

161. Farmer, C. J. and Abt, A. F.: Determination of Ascorbic Acid in Small Amounts of Blood. Proc. Soc. Exp. Biol. Med., *34:* 146–150, 1936.

162. Bessey, O. A.: A Method for the Determination of Small Quantities of Ascorbic Acid and Dehydroascorbic Acid in Turbid and Colored Solutions in the Presence of Other Reducing Substances. J. Biol. Chem., *126:* 771–784, 1938.

163. Mindlin, R. L. and Butler, A. M.: Determination of Ascorbic Acid in Plasma; Macromethod and Micromethod. J. Biol. Chem., *122:* 673–686, 1937–38.

164. Robinson, W. B. and Stotz, E.: The Indophenolxylene Method for Ascorbic Acid and Modifications for Interfering Substances. J. Biol. Chem., *160:* 217–225, 1945.

165. Butler, A. M., Cushman, M., and MacLachlan, E. A.: Determination of Ascorbic Acid in Whole Blood and Its Constituents by Means of Methylene Blue; Macro- and Micromethods. J. Biol. Chem., *150:* 453–461, 1943.

166. Roe, J. H. and Oesterling, M. J.: Determination of Dehydroascorbic Acid in Plant Tissues by 2,4-Dinitrophenylhydrazine Method. J. Biol. Chem., *152:* 511–517, 1944.

167. Bessey, O. A., Lowry, O. H., and Brock, M. J.: Quantitative Determination of Ascorbic Acid in Small Amounts of White Blood Cells and Platelets. J. Biol. Chem., *168:* 197–205, 1947.

168. Thysell, T.: Diet, Blood Ascorbic Acid, and the Capillary Resistance Test. Acta Paediat., *26:* 481–488, 1939.

169. Farmer, C. J.: Some Aspects of Vitamin C Metabolism. Fed. Proc., *3:* 179–188, 1944.

170. Haines, J. E., Klosterman, A. M., Hauck, H. M., Delaney, M. A., and Kline, A. B.: Tissue Reserves of Ascorbic Acid in Normal Adults on Three Levels of Intake. J. Nutrition, *33:* 479–489, 1947.

171. Oldham, H., Roberts, L. J., and Young, M.: Results of Providing a Liberally Adequate Diet

to Children in an Institution; Blood and Urinary Excretion Studies Before and After Improvement. J. Pediat. *27:* 418–427, 1945.

172. Kruse, H. D.: A Concept of the Deficiency States. Milbank Mem. Fund Quart., *20:* 245–261, 1942.
173. Dodds, M. L. and McLeod, F. L.: Blood Plasma Ascorbic Acid Levels on Controlled Intakes of Ascorbic Acid. Science, *106:* 67, 1947.
174. Present Knowledge of Ascorbic Acid (Vitamin C) in Nutrition. Nutrition Rev., *4:* 259, 1946.
175. Johnson, R. E., Darling, R. C., Sargent, F., and Robinson, P.: Effects of Variations in Dietary Vitamin C on Physical Well Being of Manual Workers. J. Nutrition, *29:* 155–165, 1945.
176. Crandon, J. H., Lund, C. C., and Dill, D. B.: Experimental Human Scurvy. New England J. Med., *223:* 359–369, 1940.
177. Lowry, O. H., Bessey, O. A., Brock, M. J., and Lopez, J. A.: Interrelationship of Dietary, Serum, White Blood Cell, and Total Body Ascorbic Acid. J. Biol. Chem., *166:* 111–119, 1946.
178. Linghorne, W. J., McIntosh, W. G., Tice, J. W., Tisdall, F. F., McCreary, J. F., Drake, T. G. H., Greaves, A. V., and Johnstone, W. M.: Relation of Ascorbic Acid Intake to Gingivitis. Canad. Med. Assoc. J., *54:* 106–119, 1946.
179. Dogramaci, I.: Scurvy; Scurvy of 241 Cases. New England J. Med., *235:* 185–189, 1946.
180. Vilter, R. W., Woolford, R. M., and Spies, T. D.: Severe Scurvy; Clinical and Hematological Study. J. Lab. Clin. Med., *31:* 609–630, 1946.
181. McMillan, R. B. and Inglis, J. C.: Scurvy; Scurvy of 53 Cases. Brit, Med. J., *2:* 233–236, 1944.
182. Johnstone, W. M., Drake, T. G. H., Tisdall, F. F., and Harvie, F. H.: A Study of Ascorbic Acid Metabolism of Healthy Young Canadians. Canad. Med. Assoc. J., *55:* 581–585, 1946.
183. Milam, D. F. and Wilkins, W.: Vitamin C in Normal Nutrition; The Effect of Low-Cost Diet on Plasma Levels Over a 6-Weeks Period. South. Med. & Surg. J., *104:* 191, 1942.
184. Munks, B., Kaucher, M., Moyer, E., Harris, M. E., and Macy, I. G.: Metabolism of Women During the Reproductive Cycle. XI. Vitamin C in Diets, Breast Milk, Blood, and Urine of Nursing Mothers. J. Nutrition, *33:* 601–619, 1947.
185. Smith, C. and Stuart, H.: Appraising the Nutritional Status of Mothers and Infants. A. P.-H. A. Meeting. October 1947.
186. McNee, G. Z. L. and Reid, J.: Vitamin C Nutrition in the Royal Navy and in a Section of Civilian Population During War-Time. Lancet, *2:* 538–540, 1942.
187. Walsh, G. E. K.: Vitamin C Levels in a Prisoner of War Camp. Brit. Dental J., *79:* 208–210, 1945.
188. Anderson, R. K., Calvo de la Torre, J., Serrano, G., and Payne, G. C.: A Study of the Nutritional Status and Food Habits of Otomi Indians in the Mezquital Valley of Mexico. Am. J. Pub. Health, *36:* 883–903, 1946.
189. Leeson, H. J., Webb, J. F., Ferguson, H. P., Semmons, E. M., and McHenry, E. W.: Study of Ascorbic Acid Nutrition. Canad. Med. Assoc. J., *53:* 341–344, 1945.
190. Youmans, J. B., Patton, E. W., Sutton, W. R., Kern, R., and Steinkamp, R.: Surveys of Nutrition of Populations; Vitamin C Nutrition of a Rural Population in Middle Tennessee. J. Hygiene, *42:* 254–261, 1945.
191. Kyhos, E. D., Gordon, E. S., Kimble, M. S., and Sevringhaus, E. L.: Minimum Ascorbic Acid Needs of Adults. J. Nutrition, *27:* 271–285, 1944.
192. Smith, S. L.: Human Requirements of Vitamin C. J. A. M. A., *111:* 1753–1764, 1938.
193. Holland, A. H., Jr., Canniff, J. C., and Bruger, M.: Evaluation of Vitamin C Status of Human Subjects; Studies with Intradermal Dye Discoloration, Capillary Fragility, Fasting Plasma Vitamin C Level, and Vitamin C Saturation. J. Lab. & Clin. Med., *32:* 124–129, 1947.
194. Wright, I. and Ludden, J. B.: Treatment with Vitamin C (Cevitamic Acid—Ascorbic Acid); A Method for Compensating for the Factor of Error Due to Renal Retention of Vitamin C

Found in All Previous Saturation and Blood Tests. Med. Clin. North America, *24:* 743–758, 1940.

195. Kajdi, L., Light, J., and Kajdi, C.: Test for Determination of Vitamin C Storage; Vitamin C Index. J. Pediat., *15:* 197–218, 1939.

196. Bodansky, A.: Phosphatase Studies; Determination of Serum Phosphatase. Factors Influencing Accuracy of Determination. J. Biol. Chem., *101:* 93–104, 1933.
— —: Notes on Determination of Serum Inorganic Phosphatase and Serum Phosphatase Activity. Am. J. Clin. Path., Tech. Suppl., *7:* 51–59, 1937.

197. Bessey, O. A., Lowry, O. H., and Brock, M. J.: A Method for the Rapid Determination of Alkaline Phosphatase with Five Cubic Millimeters of Serum. J. Biol. Chem., *164:* 321-329, 1946.

198. Klasmer, R.: Serum Phosphatase Activity and Clinical Rickets in Children in Jerusalem. Am. J. Dis. Child., *67:* 348–354, 1944.

199. Bodansky, A. and Jaffe, H. L.: Phosphatase Studies: Serum Phosphatase as a Criterion of Severity and Rate of Healing of Rickets. Am. J. Dis. Child., *48:* 1268–1278, 1934.
— —, — —: Serum Phosphatase in Diseases of the Bone: Interpretation and Significance. Arch. Int. Med., *54:* 88–110, 1934.

200. Youmans, J. B., Patton, E. W., Sutton, W. R., Kern, R., and Steinkamp, R.: Surveys of Nutrition of Populations. IV. Vitamin D and Calcium Nutrition of a Rural Population in Middle Tennessee. Am. J. Pub. Health, *34:* 1049–1057, 1944.

201. Bessey, O. A.: To be published.

202. Macy, Icie G.: Nutrition and Chemical Growth in Childhood. Vol. I, p. 212, 314, 316. Springfield, Illinois. Charles C. Thomas, 1946.

203. Kolmer, J. A.: Clinical Diagnosis by Laboratory Examinations. First Ed. Rev., p. 132. New York. D. Appleton Co., 1944.

204. Howland, J. and Kramer, B.: Calcium and Phosphorus in the Serum in Relation to Rickets. Am. J. Dis. Child., *22:* 105–119, 1921.

205. Gamble, J. L.: Chemical Anatomy, Physiology and Pathology of Extra-Cellular Fluid. Harvard Medical School, 1942.

206. Keys, Ancel: Physical Performance in Relation to Diet. Fed. Proc., *2:* 164–187, 1943.

207. Dill, D. B.: Life, Heat and Altitude. Harvard University Press, 1938.

208. Marriott, H. L.: Water and Salt Depletion (Croonian Lectures). Brit. Med. J., *1:* 245, 285, 328, 1947.

209. Talbott, J. H.: Heat Cramps. Medicine, *14:* 323–376, 1935.

APPENDIX

Tests which may be useful in nutrition surveys:

1. Serum Proteins
   Micro Kjeldahl-titration or nesslerization (29)
   Specific gravity-copper sulphate (9), falling drop (7), micromethod (10)
2. Hemoglobin and Iron
   Oxyhemoglobin-macromethod (27) or micromethod (3), alkaline hematin (28) copper sulphate (9)
   Serum Iron (32)
3. Vitamin A in Blood
   Macromethods-Carr Price reaction (55) (56) (57) (58)
   Micromethod (59)
4. Thiamine in Urine
   One-hour fasting excretion and load tests (oral or parenteral)
   Thiochrome procedure (86) (87) (88)
   Pyramin and thiamine determination (90)
5. Riboflavin
   a) Urinary excretion—One-hour fasting and load tests (oral or parenteral)
      Microbiological method (108)

  - Fluorometric procedures (109) (110)
  - Direct fluorometric method after load tests (111) (6)
- b) In erythrocytes (3) (128)

6. Niacin
   - One-hour fasting excretion and load tests
   - Determination of N′methyl nicotinamide (133) (134) (135)
7. Ascorbic Acid
   - In blood-plasma and leukocytes
   - Macromethods (162) (163) (164) (165) (166)
   - Micromethod (167)
   - One-hour fasting urinary excretion (50) (52)
   - Load test-estimation of blood concentration (195)
   - Load tests-urinary excretion-oral test dose (2) (175) (169), parenteral test dose (194)
8. Vitamin D
   - Phosphatase
   - Macromethod (196)
   - Micromethod (197)

SECTION IV

CLINICAL DIAGNOSIS IN NUTRITION SURVEYS

PAGE
Introduction 82
Eliciting Histories of Nutritional Disturbances 83
Symptoms of Early Deficiency States 85
Conditioning Factors 85
Physical Examinations 85
Physical Signs and Biochemical Measurements 88
Use of Therapeutic Trial as a Tool in Nutrition Surveys 90
Physical Environment 91
Population Efficiency and Nutrition 92
Composition, Scope, and Functions of Survey Teams 93

Appendix A—Check Sheet for Nutritional Surveys 94
Appendix B—References Covering Several Spontaneously Occurring Human Nutritional Diseases 100
Bibliography 113

INTRODUCTION

In the past, clinical examination during nutrition surveys has paid special attention to symptoms and signs commonly seen in individuals with known classical primary deficiency disease due to inadequate intake of food or nutrients. In addition, many examiners have looked for less obvious clinical stigmata which have been suggested by some observers as being nutritional in origin, and for signs produced by experimentally induced deficiencies.

During surveys, diagnosis of well-developed specific nutritional disease by physical examination alone is not a difficult procedure for physicians who have had experience in this field, especially if they are vigilant. Similarly, recognition of the numerous individual stigmata of so-called "sub-clinical nutritional deficiency syndromes" comes easily to those physicians who have seen them previously. The difficulty which exists is to be able to recognize that the stigmata which have been noted are due to nutritional deficiency of any cause, without further study of the individual.

A decade ago when many of the stigmata were first systematically studied (26, 27, 28, 29, 34, 40), it was hoped that they would be specific enough to allow physicians, or even specially trained nutritionists who were not qualified medically, to make an exact and unequivocal diagnosis of specific deficiency states without difficulty. Unhappily, numerous investigations have not realized this hope and current opinion of the value of special examination for the stigmata is well summarized by Adamson and his ten colleagues (1), who state:

"At the present time there is a diversity of opinion as to the specificity of many of the lesions here described. In other words, while it is generally recognized that nutritional inadequacies will produce most of them, some observers believe that some of them may also be produced by other means. Furthermore, some of the authors consider that even when the signs and symptoms are proved signs of nutritional ill-health, they may not be so specific in their etiological relationship as is implied in the following presentation."

As pointed out above, it is not easy to recognize early nutritional deficiency disease by simple inspection. Even well-developed nutritional diseases cannot always be diagnosed at a glance. For example, in his book on "Clinical Pellagra" Seale Harris (13) points out that "Pellagra may be confused with sprue, pernicious anemia, tuberculous enteritis, chronic pancreatitis, gastrogenic diarrhea and stomatitis from different causes" while Swanson (39) in a discussion of the differential diagnosis of the skin in advanced pellagra states:

"The following diseases often have skin manifestations that resemble the eruption of pellagra: acrodynia, erythema solare, erythema caloricum, erythema pernio, erythema multiforme, eczema, especially the erythematous form, dermatitis venenata, 'recurrent summer eruption', lupus, syphilis, xerodermia, erysipeloid, erysipelas."

From the onset, then, the view is presented here that there is no such thing as a single pathognomonic sign, that interpretation of clinical findings in a given individual requires careful differential diagnosis, including history, physical examination, and laboratory findings, and that in many instances a therapeutic diagnosis is necessary to settle clinical judgments.

These views are succinctly presented by Jolliffee (19) with his wealth of experience from nutrition surveys and from the clinic:

"In connection with the signs of malnutrition, it is necessary to emphasize four important points. The first is that, with but few exceptions, the signs are non-specific and may be produced by trauma other than malnutrition. No single sign of malnutrition is necessarily diagnostic; each must be evaluated in light of the history, and other signs and symptoms. Other possible causes must be ruled out. Interpretation of these signs requires all the diagnostic acumen and clinical judgment required in other branches of internal medicine."

In addition to the excerpts quoted above, the published opinions of many authors (e.g., 14, 31) make it clear that differential diagnosis is an essential part of physical examination during nutrition surveys. It should be noted that accurate differential diagnosis is difficult to accomplish when single signs or stigmata are found in a patient during a survey. Such being the case, interpretations of positive findings should only be made by physicians or dentists and not by unqualified persons. Differential diagnosis must include a consideration and knowledge of at least eleven classes of etiology. These are: congenital and hereditary; deficiency of oxygen and nutrients; parasites; trauma, including the effects of the environment; physical irritants; chemical poisons; tumors; degenerations; endocrine and metabolic; and unknown. An example of a physical sign which requires differential diagnosis when it is observed is purpura, which may have any of the above etiologies, including nutritional. In passing it should be noted that few studies have been made of the frequency distributions or incidence of the different lesions or stigmata mentioned above among normal population groups. Such data are urgently needed.

ELICITING HISTORIES OF NUTRITIONAL DISTURBANCES DURING SURVEYS

When nutritional deficiency exists it is usual to find that, as with other disease processes, some symptoms occur before physical signs appear. Moreover, spontaneous complaints of disturbed functions and of bodily and mental distress are of great value, for in the clinic more often than not it is the patient's story which confirms a diagnosis of deficiency disease. It is unfortunate that the process of obtaining a history takes such a long time. This is the main reason why the elucidation of symptoms is not more frequently used as a tool during nutrition surveys.

The questionnaire method of collecting data is not of much value. In addition to its other limitations, it is not flexible enough to use in clinical examinations. For example, a positive reply to the question, "Do you have diarrhea?" does not differentiate between the thin, burning looseness of pellagra, the copious stools of celiac disease, or the urgent bloody flux of dysentery.

Many of the symptoms of deficiency syndromes and disturbances are striking: the distressing and painful crying of a scorbutic infant, even in its mother's arms; the excessive spittle flowing in the mouth of the pellagrin; the sore tongue and burning mouth of those suffering with nicotinic acid deficiency, pernicious anemia or sprue; the difficulty with swallowing discovered in those patients who have the Plummer-Vinson syndrome; the pins and needles and hot burning feet of thiamine deficiency, and the word gaps which disturb the reading of those with nutritional scotomata, are unusual enough to catch the attention of the physician. Unfortunately, each of the symptom complexes mentioned above can arise as a result of disease processes which apparently do not have a nutritional origin. Pyogenic joint infections in babies are also distressingly painful; many patients with peptic ulcer complain of water-brash; difficulty with swallowing occurs in esophageal cancer; and pins and needles and burning of the feet are common symptoms of peripheral vascular disease and pernicious anemia.

Vital and striking complaints as described above are useful, for they facilitate diagnosis. Diagnosis is difficult when patients present few or no physical signs and complain of vague disturbances such as insomnia, loss of appetite, fatigue, weakness, palpitations, irritability, lack of ambition, and vague fears. These symptoms are classical early complaints in patients suffering with nutritional deficiency. They are also the common somatic and mental symptoms which arise with worry, anxiety, and difficult or unhappy situations in life. They may be the prodromal disturbances of serious physical and mental diseases such as tuberculosis, adrenal insufficiency, or depressive psychosis. In the clinic one cannot dismiss such patients without a long and thorough interview, a thorough physical examination, and further screening by means of laboratory examinations such as X-rays of the chest or blood sodium levels.

Thus, diagnosis is often not arrived at till days or weeks of watchful observation have passed. When such patients in the general medical clinic do in truth have a nutritional deficiency, the diagnosis is often not in hand till therapeutic diagnostic trials have been made. It is therefore obvious that symptoms such as described above, when discovered in populations, should not be accepted as *prima facie* evidence of malnutrition.

Nevertheless, despite all the difficulties cited above, histories should be obtained whenever possible during nutritional surveys. The length and detail of the history should only be limited by the time available to the surveyors. Surveys in foreign lands require at best a working knowledge of the language and at worst the services of an interpreter.

SYMPTOMS OF EARLY DEFICIENCY STATES

With both adults and children questions should be designed to discover, especially, abnormalities of growth, malfunction of the gastro-intestinal system, disturbed psyche, and ocular or visual imperfections. In addition the physician should make an effort to determine if physiological or pathological stresses are present in the group or individual under study, and to gauge the extent to which these stresses may complicate malnutrition in the group or individual.

In children and infants lack of appetite, failure to eat, failure to gain weight, retarded muscular and mental development, aversion to play, poor sleeping habits, apathy, easy bruising, and chronic diarrhea or constipation are common maternal complaints when malnutrition exists. In adults, lack of appetite, nausea especially in the morning, soreness of the lips, tongue, mouth, vagina or anus, itching or sandiness of the eyeball, lacrimation and photophobia, lassitude, fatigue, insomnia, weakness, loss of energy, emotional upsets, paresthesia of the hands, feet, or tongue, disturbed bowel function, transient edema after daily activities, easy bruising, all are symptoms which may point to a diagnosis of malnutrition.

CONDITIONING FACTORS IN SURVEYS

Physiological stresses and pathological processes (7, 17) considerably modify nutritional requirements and may adversely affect nutrition. Moreover, during surveys it is not unusual to find multiple stresses acting together to initiate or exacerbate disorders based on malnutrition (21). Common pathological conditions such as malaria, hookworm and pinworm infestation, infective hepatitis, peptic ulcer, tuberculosis, chronic diarrhea, cancer, lack of teeth, as well as other diseases, may profoundly affect nutrition. The demands of growth, the menarche, pregnancy (especially repeated pregnancy), lactation, excessive menstrual flow, heavy muscular activity, extremes of climate, religious food taboos, alcoholism, psychic disturbances, and exposure to industrial toxins, among others, may precipitate nutritional disease.

These considerations are of great importance when surveys are contemplated on special population groups, such as workers in different industries, people in homes for the aged, nurses in metropolitan hospitals, prison populations, orphans in institutions, and tribal groups.

In the planning of surveys and in the interpretation of findings, conditioning factors must always be borne in mind and the incidence and extent of the different stresses which tend to depress good nutritional status must be determined by observation and investigation of the environment in which the population under study lives, and by appropriate questions and observation of the individual.

PHYSICAL EXAMINATIONS IN NUTRITION STUDIES

All attributes of man may be expressed in distribution curves, and this method of expressing the variations in standard and malnourished populations should be more widely employed in future nutrition surveys. It is an unfortunate fact that distribution curves for individual signs of deficiency states, by sex, age, race, and environment in relation to any one sign, are almost non-existent. Even height-weight data are sparse. As good examples of the type of data which should be collected on populations we commend for attention Bean's studies of telangiectasia (3), and Stewart and Manning's study (35) of the variations in the electrocardiogram of 500 normal young men.

TABLE 1

SUGGESTED MINIMUM OBSERVATIONS TO BE REPORTED IN PUBLIC HEALTH NUTRITION SURVEYS

TYPE OF OBSERVATION	DATA TO BE RECORDED
1. Dietary History	Report of actual foods consumed. If possible some quantitative estimate should be made. Calculation of nutrient intake if desired.
2. Medical History	Environmental conditions. Relevant spontaneous complaints. If possible, conditioning factors and elicited symptoms.
3. Physical Examination	(A) Place Date Age Sex Body height Body weight (in minimum clothing, which is described) Race (White, black, red, brown, yellow, if mixed, describe) Religious group (B) If more detailed physical examinations are conducted a check list may be used for recording findings by grade. This check list should have space for recording certain physical findings which are of importance in helping the examiner to make a correct diagnosis, even though these physical findings are patently due to processes not nutritional in origin. Signs should not be listed with an etiological nomenclature. For instance acne rosacea has no etiologic connotation whereas seborrheic dermatitis of ariboflavinosis does. In the present state of knowledge etiologic nomenclature is likely to be misleading.
4. Laboratory	Whole blood hemoglobin and plasma protein by a specific gravity method. Blood smear. Clinical urinalysis, especially acetone, sugar and protein.
5. Diagnoses	Non-nutritional as well as nutritional disorders should be listed.

In interpreting results obtained from nutrition surveys, statistical analysis of data should be made with more frequency than heretofore. In passing, the following statistical facts of great importance for interpreting results of surveys of large numbers should be recalled: (a) that when a sign occurs in very low incidence normally, a small increase is significant; (b) that, contrariwise, when a given sign occurs normally with some frequency, a large increase is required for statistical significance.

In future surveys greater attention should be paid to the rigorous employment of differential diagnosis. This may be difficult even when studying an individual and is further complicated in any population group by prevalent disease (e.g. tuberculosis in American Indians; malaria in the tropics; hookworm in some of the southern states), by environmental stresses (e.g., effects of altitude on the Peruvians), and by factors of personal hygiene (e.g., non-bathing in cold climates). Nutrition surveys should include these considerations. Since the normal can only be recognized by comparison with the abnormal and as differential diagnosis of abnormal physical signs can only be unravelled by those who are trained in this skill, physicians should be included in any nutrition survey team.

TABLE 2
PHYSICAL EXAMINATIONS: SOME SIGNS OFTEN ATTRIBUTED TO NUTRITIONAL DISTURBANCES. AFTER JOLLIFFE AND MOST (20)

ORGANS	SIGN
Eyes	Conjunctivitis, dryness, photophobia, lachrymation, Bitot's spots, pterygia, scleral thickening, corneal cloudiness, obvious corneal vascularization.
Mouth, Tongue and Teeth	Cheilosis, glossitis, stomatitis, gingivitis, poor oral hygiene, angular fissure in absence of false teeth, fluorosis.
Skin	Petechial hemorrhages, purpura, symmetrical dermatitis, follicular hyperkeratosis, acneiform eruption, facial seborrhea.
Extremities	Muscular weakness, tenderness and atrophy, nerve tenderness, loss of vibratory sense, loss of tendon reflexes, edema.

Standardization of survey methods has worked well for the physical scientists and especially for the astronomers, who for 300 years have all made star maps according to internationally agreed criteria. The U. S. Bureau of Standards, for example, provides certain reference chemicals which most analytical chemists use. Therefore, in order to provide comparable data in the field of nutrition which can be read critically by any competent surveyor, a plea is made for standardization.

When public health nutrition surveys by individuals or teams are contemplated, consideration should be given to the value of this concept, and plans should be made to use techniques of a standard nature. Table 1 lists suggestions for minimal observations in public health nutrition surveys.

Uniform criteria and definitions of the many physical signs sought for during nutrition surveys are not available at present. In the meanwhile, it is suggested that the reader consult the Food and Nutrition Board publication, "Handbook on Clinical Diagnosis of Deficiency States" (in press) which contains a large number of photographs and detailed descriptions of lesions. Appendix A presents a suggested check list for recording of physical findings. It should not be employed as a substitute for a thorough physical examination. A list of clinical publications on some important diseases and syndromes of nutritional origin spontaneously occurring in man will be found in Appendix B.

Study of clinical descriptions of these conditions in text books and elsewhere, and observations when possible in the clinic and hospital, will assist in making accurate diagnosis during a survey. In the proposed check list special attention has been paid to lesions of the skin, of the lips and mouth, and of the neuro-muscular system, because physical signs of nutritional disturbance appear early in these organs, as shown in Table 2 which is extracted from an article by Jolliffe and Most (20).

In infants and children, disturbances of growth are important physical signs of nutritional inadequacy, and where possible anthropomorphic data should be recorded by the Wetzel grid (41) or through simple techniques as described by Stuart and Meredith (36, 37, 38).

In both children and adults, various clinical laboratory tests such as X-rays of the bones for detecting disturbances of calcium metabolism, vitamin D deficiency and scurvy, fluoroscopy of the small bowel for abnormal activity and pattern, and other examinations such as electrocardiograms, measurement of venous pressure and circulation time, can be made at the discretion of the surveyors.

PHYSICAL SIGNS AND BIOCHEMICAL MEASUREMENTS IN NUTRITION SURVEYS

In an attempt to measure quantitatively nutritional disease processes, biochemical analyses have been made of the excreta, the blood cells, the body fluids and the body tissues. These have been made during the fasting state, before and after load tests or other therapeutic measures, and have included measurements of minerals, vitamins, fats, carbohydrates, and proteins, their metabolic derivatives, and normal and abnormal products of metabolic reactions in which nutrients take a part. Measurements of hemoglobin, blood prothrombin, alkaline phosphatase, blood calcium, serum albumen, and ketone bodies are accepted by most workers as indices of nutritional adequacy or inadequacy, *when properly interpreted in the light of clinical findings and other biochemical measurements*. For example, alterations of hemoglobin levels in a population may be due to chronic malaria, helminthiasis, lead poisoning, sojourn at high altitudes, dehydration, muscular activity, or inadequate nutrition. Interpretation of hemoglobin levels in any population therefore requires a discerning analysis in the light of other findings. These have been discussed in some detail in the section on biochemistry, in the present publication. The present paragraphs are therefore devoted to a discussion of the correlations and non-correlations between physical signs and biochemical data.

During the war, nutrition surveys by biochemical and clinical methods were made on soldiers all over the world, and in most instances a lack of correlation was found between individual clinical stigmata as listed in Table 2 and biochemical measurements of nutrients. The reasons for this lack of correlation were discussed in a study of over 1600 soldiers in the tropics (23) which states:

"The few correlations between individual clinical stigmata and biochemical measurements were between small average differences; their physiological interpretation was not apparent and they could not be used for diagnostic purposes in individual cases. A different set of results might be expected in a population suffering from florid nutritional disease. Lack of correlation between biochemical and clinical findings has been reported by Milam and Anderson (1944) in North Carolina, by Riggs et al (1943) in Canada, and by Youmans et al (1942) (1943) in Tennessee, and some of the many possible contributing causes for this situation have been discussed by Sinclair (1944) and by Dann and Darby (1945). In a well-controlled laboratory experiment, imposition of a deficiency diet is followed in order by chemical unsaturation of the tissues, by impairment of functions without histological changes, and finally by definite pathological changes in the tissues. In natural environments the interpretation of changes is difficult. A subject previously unsaturated may have had recent access to nutrients enough to raise his tissue concentration without restoring function or reversing pathological changes. Again, disturbance of nutrition is only one of many possible causes of functional impairment. Finally, a given pathological change, such as cheilosis, may result from one or many processes other than nutritional deficiency (Machella, 1942; Machella and McDonald, 1943). Pott (1945) has emphasized another phase of the lack of correlation among chemistry, function and pathology. Many characteristics of a population can be expressed in distribution curves. An individual subject provides a single point on each curve but there is no valid reason to expect that measurements on him will always fall in the same portion of every curve. For instance, there should be no occasion for surprise that a man should be classified as having a high degree of fitness and yet as having a low serum ascorbic acid and at the same time normal optic discs. Since it is excessively uncommon for a single type of observation to be diagnostic for any specific disease, extreme caution should be used in interpreting data on the lower end of distribution curves. So far as nutrition is concerned, it may be that a whole population is so well fed that even those whose measurements are on the lower ends of the distribution curve are by any reasonable standard not at all deficient, and this is the exact interpretation we place on the data for U. S. troops in the Pacific. In contrast, some of the distribution curves for the Indian troops had lower values than those of U. S. troops and there were in Burma actual cases of ill health associated with positive clinical findings and poor biochemical states."

Observations such as the foregoing have led us to believe that at present the evaluation of nutritional status by biochemical measurements made on a single occasion may give good results, but only when interpreted as one part of a detailed clinical study of an individual. When applied to generally healthy population groups such as soldiers, biochemical observations made on a single occasion will be useful but only as a check on recent dietary intake (6). They will not provide a valid measure of sub-clinical deficiency, unless repeated enough times to show whether the population under study is remaining static or is going up or down with respect to the nutrient in question, e.g. serial measurements of levels of ascorbic acid in the plasma (32).

In the future it may become possible by chemical measurements made on a single occasion to conclude correctly that a given population is on the average either well-nourished, grossly deficient and diseased, or suffering from borderline or early deficiency states. As yet, sufficient systematic evidence has not been collected through surveys to allow such conclusions. It would be highly useful if a complete battery of biochemical measurements, such as have been used on over 4,000 soldiers in different parts of the world (16), could be applied systematically to population groups suffering from florid deficiency states. Such surveys can contribute to the definition of borderline or early deficiency by delineating the differences between vigorous, healthy, and well-fed populations and the unfortunates who have frank nutritional disease.

USE OF THERAPEUTIC TRIALS AS A TOOL IN NUTRITION SURVEYS

One accepted method of confirming clinical diagnoses of nutritional disturbances or diseases is to observe the effect of therapy on the patient or on the group studied. For example, a good response to therapy in an individual patient with ariboflavinosis will occur when daily therapy with riboflavin is given for one to three weeks. However, the patient will relapse and physical signs will eventually recur when the riboflavin therapy is stopped, *provided that he eats the same diet, does the same work, and lives in the same environment* as he did when he was first seen by the physician. If riboflavin is given a second time the patient will again show a therapeutic response to riboflavin and with cure of the disease the clinical diagnosis of ariboflavinosis is completely confirmed (41). The response—relapse—response method of testing a nutrient is a thorough but difficult method of conducting a therapeutic diagnostic trial of vitamins, amino acids, or protein. Another method of conducting diagnostic therapeutic trials, and one which is more applicable to populations, is to divide the population under survey into two numerically equivalent groups, equally distributed with regard to age, sex, body build, activity, dietary intake, and clinical findings. Both groups must remain in the same environment and eat the same diet. One group is then given the vitamin or vitamins suspected of being deficient in the diet, either orally or parenterally. The second group is given a placebo which resembles the therapeutic agent as closely as possible in appearance and taste. Comparisons of the two groups are made at the end of the period of therapy. Any differences which are found can be attributed to the effects of therapy. When this kind of testing is done it is important that the physicians and other personnel who do the testing should not know which of the patients are getting placebos and which are getting therapeutically active substances.

A more rigid control is obtained by dividing the population under study into three equivalent groups, one group being given therapy, one group being given placebos, and one group being given no therapy whatsoever. The reason for doing this is that Wolf has recently shown (43) that placebos per se may have a profound effect on symptoms and signs in a population. In addition, Borsook (7) who gave placebos and vitamin supplements to aircraft workers in California found that "a larger number of the placebo than of the vitamin group reported benefits with respect to eye symptoms, weight gain, and miscellaneous conditions." If differences in the three groups occur, the responses or lack of responses in the untreated group and the placebo group will serve as a base line for measuring the response of the group given nutrient therapy. Curative effects of therapy over and above those observed in the placebo and untreated control groups can be attributed to the nutrient under test, again provided that the basic pre-study dietary intakes, activity, and environment of the three groups have remained unchanged. At this point it must be emphasized that, while the majority of patients with malnutrition will respond to specific therapy with nutrients, there are some patients with long-standing nutritional disease whose lesions are irreversible. When this happens, repair of tissue will not take place, no matter how much therapy is given nor for how long. Irreversible lesions of this sort usually involve the central nervous system.

When vitamins are used for therapeutic diagnostic purposes it is customary to give them each day in amounts which are five times the recommended daily allowances for vitamins of the National Research Council, but this is not a hard and fast rule.

It is earnestly hoped that, when nutrition surveys are contemplated on populations, serious consideration will be given to repetitive surveys as means of testing the diagnostic value of vitamins or other nutrients employed as corrective agents.

PHYSICAL ENVIRONMENT IN NUTRITION SURVEYS

There is a seasonal variation in the incidence of some diseases such as upper respiratory infections and pellagra. In the field of nutrition this seasonal variation is further complicated by the usual harvest cycle, which tends to make populations better fed in the summer and autumn than in the winter and spring. For these reasons it is necessary to consider environmental effects in any survey, and, if possible, to examine the same groups repeatedly. Conclusions reached during a single survey made in one season may not be valid for the group at any other time of the year.

Many physical signs which may or may not be related to nutritional state are produced or aggravated by environmental trauma. Examples are pellagrous dermatitis, which is usually intensified by sunshine; the keratitis and conjunctivitis of snow-blindness, which are worst on gray, cloudy spring days; folliculosis, which is exacerbated by heavy winter clothing and lack of bathing, or by sweating and hard activity in the summer; changes in tendon reflexes, which may be associated with hard muscular work in environmental extremes; and the color of the skin, which is markedly altered by large changes in altitude.

Data on environmental influences on physical signs are remarkably scarce. Very little experimental work has been performed in this connection, and interpretation of the few field observations available is always difficult because of a multiplicity of complicating factors. Nutrition surveys can render a most valuable contribution to science by systematic study of physical signs as they vary in the same group under varying environmental conditions.

The consumption of foods and fluid is markedly affected by environmental conditions. Consumption of 5,000 calories or more per man per day is a common phenomenon among soldiers in an Arctic winter (16) and 4 liters or more of water per day are necessary to maintain water balance in the desert in summer (2). At the same time, calorie requirements in the desert and moist tropics are probably less than they are in colder environments (17). Similarly, evidence is accumulating to show that some vitamin requirements for man may vary with the environmental temperature, an example being ascorbic acid as studied in troops exposed to Arctic cold (23).

As yet, most national and international bodies have taken environmental factors into account to only a limited extent if at all in setting up tables of recommended dietary allowances. Evidence such as that mentioned above suggests that eventually such considerations may be important. A significant contribution in this direction can be made by nutrition surveys.

POPULATION EFFICIENCY AND NUTRITION

There is a widespread belief among nutritionists that malnutrition in man is responsible for physical inefficiency and increased susceptibility to infectious diseases. For example, a report of a recent survey (1) concludes with the following statement: "... the poor nutritional status of the people of Newfoundland may well be in a large part responsible for their impaired health and efficiency." In this particular field of nutritional investigation clear-cut and convincing data are extremely scarce (22). For instance, few doubt that there is a close correlation between malnutrition and a high incidence of tuberculosis, and several well-known studies on this point have shown such a correlation, but clear-cut interpretations are complicated by many other socio-economic difficulties. Crowding, poor sanitation, malnutrition, and tuberculosis go hand in hand, and no one has been able to study tuberculosis purely in relation to malnutrition. As Getz remarks (11); "The concept that malnutrition predisposes to infectious disease and particularly tuberculosis, has been accepted largely on empirical grounds."

When gross signs of active and severe nutritional disease are found, loss of efficiency very often parallels organic involvement: for example, languor and weakness are commonly present in the nutritional anemias. On the other hand, when definite minor vitamin deficiencies and physical signs are found in human populations the problems of measurement of efficiency are so bound up with motivation and environmental problems as to be well nigh uninterpretable at this juncture on the basis of nutritional deficiency alone (22).

Caloric deficiency, whether acute or chronic, shows some pretty correlations between efficiency and the degree of deficiency. Kraut and Muller (25) demonstrated an almost quantitative relationship in Ruhr miners between coal production and caloric intake. The fewer the calories, the less coal was mined, despite the patriotic incentive to produce maximally during a war. It has also been observed that slight caloric deficiencies which cannot be recognized clinically or by present biochemical techniques in an individual can, when widespread in a group, diminish the efficiency of the group (16). Similar good correlations can be noted between dehydration and loss of efficiency (2, 30), between oxygen lack and dyspnea (12), and to a lesser degree between iron-deficiency anemia and weakness.

When protein or vitamin subnutrition exists (by North American standards) some data are apparently at variance with present concepts. For instance, among the Gurkhas (inhabitants of the independent Himalayan State of Nepal) excellent physical fitness and tactical military efficiency are compatable with very low levels, by North American standards, of intake of several important nutrients and, in addition, very low levels of these nutrients in the blood and urine (16). Moreover, it is common clinical knowledge that some waterlogged patients with cardiac beri-beri show a surprising ability to work without dyspnea, in contrast to patients in heart failure as a result of other diseases, such as rheumatic fever. In addition, among laborers doing heavy work, calorically well-nourished pellagrins and scorbutics have been observed to be able to do a surprising amount of work provided their calorie intake is adequate, when compared with individuals who are well nourished but untrained and sedentary.

Nevertheless, experimentally induced vitamin deficiencies in man seem to show some correlations between the development of physical signs and loss of efficiency (15, 24). One is tempted to explain the apparent contradictions by postulating that experimentally produced deficiency syndromes in man are not the exact counterparts of naturally occurring borderline vitamin deficiencies, as presently diagnosed in the field or in the clinic. For example, Crandon (9), living on a vitamin-C-free diet, developed perifollicular hemorrhages in the skin of the legs but did not develop spongy bleeding gums, anemia, or a positive tourniquet test, three common findings in scurvy. Another explanation is that many observers have accepted certain minor aberrations in surface tissues as being pathognomonic or patent signs of nutritional deficiency disease. That this is an unsound concept has been ably demonstrated by Dann and Darby (10) and has been discussed above. Therefore, it is believed that further investigations are now required concerning the single and concerted effects of different types of malnutrition and environmental stresses on the physical and mental efficiency, and on the health, of population groups. One way of obtaining these data is by conducting well-rounded nutritional surveys.

Measurements of efficiency are notoriously difficult to interpret, because "good" scores depend on good motivation; because reproducibility of data depends on the elimination of the learning phenomenon; because efficiency or "good" scores in one type of test often do not correlate with efficiency or "good" scores measured in another way; and because efficiency and "good" physical fitness obtained in tests do not imply efficiency or fitness for true life situations. The most widely used physical fitness test, the Harvard step test (16), which is a useful test for assessing active young adults, cannot be used for testing children, the aged, or the infirm. We do not recommend the routine use of any "fitness test" in general surveys.

COMPOSITION, SCOPE, AND FUNCTIONS OF SURVEY TEAMS

The collection of data during nutrition surveys depends a great deal on the available personnel and equipment. For example:

A. One trained layman can conduct a height-weight survey, using standard scales and measurements.
B. One physician with clerical help can do a rapid survey on general health.
C. One dietitian or home economist can conduct a rough quantitative survey of food intake.
D. One biochemist can make measurements of blood and urine chemistry, given space and equipment.

Combinations of individuals noted in A, B, C, and D above can do adequate complete surveys in temperate zones where public health is good. In areas of environmental hazard and prevalent disease, specialists are required in addition to other team personnel (e.g., an X-ray technician in areas where tuberculosis is prevalent; a parasitologist in the tropics). A team that worked successfully for the Army included a physician, a biostatistician, a nutrition officer, a food specialist, and a physician-biochemist. An ideal survey team would include a wide variety of specialists, such as sociologists, agronomists, food technologists, and anthropologists, among others, and would make repetitive surveys as outlined previously.

Finally, in our opinion a nutrition survey should take into account the total environment of the group under study and is of little public health value unless it can include practical suggestions for improvement of health (if necessary), made by the competent experts, whether anthropologists, agronomists, or physicians.

SUMMARY

The view is supported that in medical nutrition surveys there is no such thing as a single pathognomonic physical sign of specific nutritional deficiency; that interpretation of clinical findings in a given individual requires careful differential diagnosis, including history, physical examination, and laboratory findings; and that in many instances, a therapeutic diagnosis is necessary to settle clinical judgments, with the reservation that irreversible tissue change as a result of prolonged disease sometimes does not respond to any therapy.

The composition, scope, and functions of survey teams of various types are discussed, with emphasis on the idea that a medical nutrition survey is of little value unless it takes into account the total environment of the group under study and unless it can include practical suggestions for improvement of health (if necessary) by competent experts, whether anthropologists, agronomists, or physicians.

A strong plea is made for standardization of methods among various teams, and suggested minimum observations are presented, along with a proposed check list for physical examination.

APPENDIX A

CHECK SHEET FOR NUTRITIONAL SURVEYS

Wet...°C....°F.
Place................Date..........Outdoor Temp....Dry...°C....°F.
Altitude..................Meters............
Subject's Name............................Age........Sex......
Race: White..Black..Red..Yellow..Brown..Mixed..Other..
National Group.......................
Religious Group.......................
History: ....None....Obtained by Physician, Interpreter.
Spontaneous Complaints....None. If other detail:
....
....
....
....

Elicited Complaints....None. If other detail:
....
....
....
....

Conditioning Factors....None. If other detail:
....
....
....
....

Dietary History: ....None. Obtained by Physician, Dietitian, Home Economist, Interpreter,........
Recorded on Dietary Form..
If other, detail: ....
....
....

Physical Examination:

Height: Cms. with footgear........Cms. without footgear......
Height of heels (Approx)...........................cms.
Weight: Kgs. with clothes........Kgs. without clothes......Kgs.
Weight of clothes (Approx)...........................Kgs.

General Condition:

....Up and about..........Bedridden............Other..................
....Alert............Apathetic............Other.........................
....Well Developed........Poorly............Other...................
....Obese............Well Nourished........Thin........................
........Wasted........Other........
....Other

EYES:

........No abnormalities
........Disturbances of vision: If present, detail...............................
........Photophobia
........Dryness
........Disturbance of movement: If present, detail.........................
........Bitot's spots
........Gross changes in opacity of sclera, 1..................Slight:
2..................Moderate: 3..................Severe.
........Gross changes in opacity of cornea
........Sclerocorneal vascularity. 1..................Slight:
2..................Moderate: 3..................Severe.
........Old corneal injury
........Follicular conjunctivitis

........Gross conjunctivitis: 1.........Slight: 2.........Moderate;
3...........Severe:
........Injection of vessels at equator of bulbar conjunctiva
........Pterygia
........Pingueculae
........Not examined
........Other: If present, detail

LIPS AND MOUTH:

........No abnormalities
........Aphonia: If present, detail
........Angular fissure in absence of false teeth
........Cheilosis
........Color of tongue:........Normal: If not detail,........................
........Edema of tongue: 1.....Slight; 2.....Moderate; 3.....Severe.
........Papillae and mucous membrane of tongue...Normal: If other detail.
........Stomatitis: 1.....Slight; 2.....Moderate; 3.....Severe.
........Chronic gingivitis: 1.....Slight; 2.....Moderate; 3.....Severe
........Active acute inflammation of dental margin. 1.........Slight;
2.........Moderate; 3.........Severe.
........Retraction or recession of gums
........Swelling of interdental papillae
........Bleeding of gums, either spontaneous or in slight trauma.
........Oral hygiene: 1.........Good; 2.........Fair; 3.........Poor.
........Abnormal pigmentation of buccal mucosa.
If present, location and nature:..
........Not examined
........Other: If present, detail:..

SKIN:

........No abnormalities
........Anemia of palms and mucous membranes.
........Xerosis
........Follicular hyperkeratosis; 1....Slight; 2....Moderate; 3....Severe.
If present, area...
........Acneiform eruption; 1.....Slight; 2.....Moderate; 3.....Severe.
If present, area...
........Seborrheic dermatitis: If present, area.............................
........Psoriasis: If present, area..
........Acne rosacea
........Eczema: If present, area...
........Telangiectasis: If present, area...................................
........Acrodynia
........Jaundice

........Dermatitis (pellagrous or pellagrous-like complex)

Erythema	....
Pigmentation	....
Depigmentation	....
Blisters	....
Cracks	....
Thickening	....
Infected	....

Area (describe)..
1.........Acute; 2.........Chronic; 3.........Slight;
4.........Moderate; 5.........Severe.

........Thickening and pigmentation of skin at elbows or knees. If present, details..

........Miliaria: 1.....Slight; 2.....Moderate; 3.....Severe.
If present, area..

........Traumatic dermatitis: 1....Slight; 2....Moderate; 3....Severe.
If present, area..

........Dermatitis of fungus infection: 1.....Slight; 2.....Moderate;
3.....Severe. If present, area..

........Periofolliculosis without hemorrhage.

........Petechial hemorrhages. If present, area..............................

........Purpura: If present, area..

........Not examined.

........Other: If present, detail. (Especially "cracked" skin, "blackheads", "whiteheads", suborbital pigmentation)

TRUNK:

Heart

........Normal

........If abnormal, detail..

........Pulse rate
........Blood pressure
{Position when measured.

Chest

........Normal

........If abnormal, detail

Abdomen

........Normal

........Liver enlarged: Detail.

........Spleen enlarged: Detail

........Other abnormalities: Detail

ENDOCRINE AND LYMPHATIC:

........Normal

........If abnormal: Detail

EXTREMITIES:

........No abnormalities
........Brittleness of nails
........Grooving or pitting of nails
........Spooning of nails
........Pigmentation. If present, area......................................
........Palmar erythema
........Epidermophytosis of hands or feet. 1.....Mild; 2.....Moderate;
3.....Severe. If present, location...................................
........Not examined
........Other; If present, detail

NEUROMUSCULAR AND LOCOMOTOR:

........No abnormalities
........Muscular weakness
........Knee jerks absent: 1.....Right; 2.....left; 3.....Both.
........Ankle jerks absent: 1.....Right; 2.....Left; 3.....Both.
........Tenderness of belly of gastrocnemius
........Nerve tenderness: If present, location................................
........Hyperesthesia: If present, location..................................
........Vibratory sense lost on malleoli: 1.....Right; 2.....Left; 3.....Both.
........Anesthesia: If present, location............type......................
........Symmetrical muscular atrophy in extremities.
........Pretibial pitting edema
........Pitting edema of feet
........Pitting edema over sacrum
........Spasticity: If present, detail
........Romberg's sign
........Squatting test positive
........Signs of rickets. If present, detail
........Signs of osteomalacia. If present, detail
........Other bone disturbances. If present, detail
........Not examined
........Other: If present detail

FOR CHILDREN AND ADOLESCENTS.

Age........Years........months.
Height (without shoes)..................cm. or............inches
Weight (minimum clothes).................kg. or............lbs.
Hip width.................cm. or.................inches
Chest circumference.................cm. or...........inches
(middle of inspiration-expiration)

Skin and fat thickness
Back..............cm. or..............inches or..............grade
Ilium..............cm. or..............inches or..............grade

DETAILED DESCRIPTIONS OF ABNORMAL FINDINGS

Diagnoses
Nutritional Status Satisfactory..............
Nutritional Status Abnormal..............Specify..................
No other disease processes..............
Other disease processes.. ....
If present, diagnosis.

SECTION IV

APPENDIX B

A short bibliography of clinical publications on some important diseases and syndromes which occur spontaneously in man and which are or may be related to malnutrition.

I. *WATER*
  A. *Dehydration*
    1. Marriott, W. McK.: Anhydremia. Physiol. Rev., *3:* 275–294, 1923.
    2. Gamble, J. L.: Dehydration. New England J. Med., *201:* 909–917, 1929.
    3. Nadal, J. W., Pedersen, S., and Maddock, W. G.: Comparison Between Dehydration from Salt Loss and from Water Deprivation. J. Clin. Invest., *20:* 691–703, 1941.
    4. Marriott, H. L.: Water and Salt Depletion (Croonian Lectures). Brit. Med. J., *1:* 245, 285, 328, 1947.
  B. *Dehydration Syndrome*
    1. Pitts, G. C., Johnson, R. E., and Consolazio, F. C.: Work in the Heat as Affected by Intake of Water, Salt, and Glucose. Am. J. Physiol., *142:* 253–259, 1944.
    2. Adolph, E. F.: The Physiology of Man in the Desert. New York. Interscience Publishing Co., 1947.
  C. *Heat Exhaustion*
    1. Ladell, W. S. S., Waterlow, J. C., and Hudson, M. F.: Desert Climate; Physiological and Clinical Observations. Lancet, *2:* 491, 527, 1944.

II. *CALORIES*
  A. *Obesity*
    1. Epstein, A. A.: Clinical and Biological Considerations of Obesity and Certain Allied Conditions. Bull. New York Acad. Med., *10:* 389–414, 1934.
    2. Newburgh, L. H. and Johnston, M. W.: Obesity. Med. Clin. North America, *27:* 327–347, 1943.
  B. *Starvation*
    1. Benedict, F. G.: A Study of Prolonged Fasting. Carnegie Institution of Washington, 1915, p. 416.
    2. Fleming, G. B.: Investigation into Metabolism in Infantile Atrophy, with Special Reference to the Respiratory Exchange. Quart. J. Med., *14:* 171–186, 1921.
    3. Benedict, F. G.: Metabolism During Starvation and Undernutrition. New York Med. J., *115:* 249–256, 1922.
    4. Fleming, G. B. and Hutchinson, H. S.: Metabolism in Undernourished Infants. Quart. J. Med., *17:* 339–357, 1924.

5. Wilkinson, P. B.: Deficiency Diseases in Hong Kong. Lancet, *2:* 655–658, 1944.
6. Lipscomb, F. M.: Medical Aspects of Belsen Concentration Camp. Lancet, *2:* 313–315, 1945.
7. Burger, G. C. E., Sandstead, H. R., and Drummond, J.: Starvation in Western Holland. Lancet, *2:* 282–283, 1945.
8. Spillane, J. D.: Partial Starvation in Prisoners of War. Lancet, *2:* 317–318, 1945.
9. Leyton, G. B.: Effects of Slow Starvation. Lancet, *2:* 73–79, 1946.
10. Burgess, R. C.: Deficiency Diseases in Prisoners of War at Changi, Singapore, February 1942 to August 1945. Lancet, *2:* 411–418, 1946.
11. Mitchell, J. B. and Black, J. A.: Malnutrition in Released Prisoners of War and Internees at Singapore. Lancet, *2:* 855–862, 1946.

C. *Ketonuria with Involuntary Dehydration*

1. Kark, R. M., Johnson, R. E., and Lewis, J. S.: Defects of Pemmican as an Emergency Ration for Infantry Troops. War Medicine, *7:* 345–352, 1945.

III. *PROTEINS*

A. *Nutritional Edema*

1. Maver, M. B.: Nutritional Edema and "War Dropsy". J. A. M. A., *74:* 934–941, 1920.
2. Weech, A. A. and Ling, S. M.: Nutritional Edema; Observations on Relation of Serum Proteins to Occurrence of Edema and to Effect of Certain Inorganic Salts. J. Clin. Invest., *10:* 869–888, 1931.
3. Weech, A. A.: Fluid Distribution and Edema. Bull. New York Acad. Med., *10:* 269–288, 1934.
4. Youmans, J. B.: Nutritional Edema. *In* International Clinics, IV. Philadelphia. J. B. Lippincott Co., 1936.
5. Kurnick, N. B.: War Edema in the Civilian Population of Saipan. Ann. Int. Med., *28:* 782–789, 1948.

B. *Growth and Development*

1. Gardiner-Hill, H.: Abnormalities of Growth and Development; The Clinical and Pathological Aspects (Oliver Sharpey Lecture). Brit. Med. J., *1:* 1302–1308, 1937.

IV. *FATS, FATTY ACIDS*

A. *Fat Deficiency*

1. Hansen, A. E. and Burr, G. O.: Studies in Iodine Absorption of Serum in Rats Fed on Fat-Free Diets. Iodine Numbers of Serum Lipids in Rats Fed on Fat-Free Diets. Proc. Soc. Exp. Biol. and Med., *30:* 1200–1203, 1933.

B. *Infantile Eczema*

1. Hansen, A. E.: Serum Lipids in Eczema and Other Pathologic Conditions. Am. J. Dis. Child., *53:* 933–946, 1937.

C. *Fibrocystic Disease of Pancreas*

1. Andersen, D. H.: Cystic Fibrosis of the Pancreas and its Relation to

Celiac Disease; Clinical and Pathological Study. Am. J. Dis. Child., *56:* 344–399, 1938.

V. *MINERALS*

A. *Acid-Base Imbalance*

1. Darrow, D. C.: The Pharmacopea and the Physician Treatment of Dehydration, Acidosis, and Alkalosis. J. A. M. A., *114:* 655–660, 1940.
2. Singer, R. B. and Hastings, A. B.: An Improved Clinical Method for the Estimation of Disturbances of the Acid-Base Balance of Human Blood. Medicine, *27:* 223–242, 1948.

B. *Iron Deficiency Anemia (Infancy, Adolescence, Pregnancy, Menopause, Plummer-Vinson Syndrome)*

1. Suzman, M. M.: Syndrome of Anemia, Glossitis and Dysphagia; Report of Eight Cases with Special Reference to Observations at Autopsy in One Instance. Arch. Int. Med., *51:* 1–21, 1933.
2. Heath, C. W. and Patek, A. J., Jr.: The Anemia of Iron Deficiency. Medicine, *16:* 267–350, 1937.
3. Fullerton, H. W.: Iron Deficiency of Late Infancy. Arch. Dis. Childhood, *12:* 91–110, 1937.
4. Josephs, H. W.: Iron Metabolism in Infancy; Factors Influencing Iron Retention on Ordinary Diets. Bull. Johns Hopkins Hosp., *65:* 145–166, 1939.

C. *Tetany (Infantile and Adult)*

1. Pincus, J. B. and Gittleman, I. F.: Infantile Tetany; Metabolic Study. Am. J. Dis. Child., *51:* 816–822, 1936.
2. Bakwin, H.: Pathogenesis of Tetany of the Newborn. Am. J. Dis. Child., *54:* 1211–1226, 1937.

D. *Osteomalacia*

1. Maxwell, J. P.: Further Studies in Adult Rickets (Osteomalacia) and Foetal Rickets. Proc. Roy. Soc. Med., *28:* 265–300, 1935.
2. Maxwell, J. P.: The Modern Conception of Osteomalacia and Its Importance to China. Chinese Med. J., *49:* 47–52, 1945.
3. Liu, S. H. et al.: Calcium and Phosphorus Metabolism in Osteomalacia: Effect of Varying Levels and Ratios of Calcium to Phosphorus Intake on Their Serum Levels, Paths of Excretion, and Balances, in the Presence of Continuous Vitamin D Therapy. J. Clin. Invest., *16:* 603–611, 1937.
4. Taylor, G. F. and Day, C. D. M.: Osteomalacia and Dental Caries. Brit. Med. J., *2:* 221–222, 1940.
5. Maxwell, J. P. and Pi, H. T.: Cataract in Adult Rickets (Osteomalacia). Proc. Roy. Soc. Med., *33:* 777–782, 1940.
6. Kenny, M.: A Case of Osteomalacia. Proc. Roy. Soc. Med., *34:* 801–804, 1941.
7. Albright, F., Burnett, C. H., Parson, W., Reifenstein, E. C., and Roos, A.: Osteomalacia and Late Rickets. The Various Etiologies Met in the U. S., with Emphasis on that Resulting from a Specific Form of

Renal Acidosis, the Therapeutic Indications for Each Etiological Sub-Group, and the Relationship between Osteomalacia and Milkman's Syndrome. Medicine, *25:* 399–477, 1946.

E. *Osteoporosis*
  1. Mendenhall, A. M. and Drake, J. C.: Calcium Deficiency in Pregnancy and Lactation; Clinical Investigation. Am. J. Obst. & Gynec., *27:* 800–807, 1934.
  2. Camp, J. D. and McCullough, J. A. L.: Pseudofractures in Diseases Affecting the Skeletal System. Radiology, *36:* 651–663, 1941.

F. *Milkman's Syndrome*
  1. Milkman, L. A.: Pseudofractures (Hunger Osteopathy, Later Rickets, Osteomalacia), Report of Case. Am. J. Roentgenol., *24:* 29–37, 1930.
  2. Milkman, L. A.: Multiple Spontaneous Ideopathic Symmetrical Fractures. Am. J. Roentgenol., *32:* 622–634, 1934.
  3. Edeiken, L. and Schneeberg, N. G.: Multiple Spontaneous Idiopathic Symmetrical Fractures (Milkman's Syndrome). J. A. M. A., *122:* 865–870, 1943.

G. *Heat Cramps* (*Stokers' Cramp*, *Miners' Cramp*)
  1. Talbott, J. H.: Heat Cramps. Medicine, *14:* 323–376, 1935.
  2. Dill, D. B.: Life, Heat and Altitude; Physiological Effects of Hot Climates and Great Heights. Harvard University Press, 1938.
  3. Talbott, J. H.: Handbook of Nutrition; Water and Salt Requirements in Health and Disease. J. A. M. A., *119:* 1418–1425, 1942.

H. *Goiter*
  1. Marine, David: The Pathogenesis and Prevention of Simple or Endemic Goiter. Proc. Inst. Med., *5:* 31–46, 1924.
  2. Marine, David: The Pathogenesis and Prevention of Simple or Endemic Goiter, J. A. M. A., *104:* 2334–2341, 1935.
  3. Means, J. H.: The Thyroid and Its Diseases. Philadelphia. J. B. Lippincott Co., 1937.

VI. *FAT SOLUBLE VITAMINS*

A. *Vitamin A Deficiency* (*General*)
  1. Widmark, E.: Vitamin A Deficiency in Denmark and Its Results. Lancet, *1:* 1206–1209, 1924.
  2. Sweet, L. K. and K'Ang, H. J.: Clinical and Anatomic Study of Avitaminosis A Among the Chinese. Am. J. Dis. Child., *50:* 699–734, 1935.
  3. Loewenthal, L. J. A.: The Manifestations of Vitamin A Deficiency in Man. Ann. Trop. Med., *29:* 407–413, 1935.
  4. Nicholls, L. and Nimalasuriya, A.: Bitot's Spots in Ceylon. Lancet, *1:* 1432–1434, 1939.

B. *Night Blindness*
  1. Bloch, C. E.: Blindness and Other Diseases in Children Arising from Deficient Nutrition (Lack of Fat-Soluble Vitamin A Factor). J. Dairy Sci., *7:* 1–10, 1924; Am. J. Dis. Child., *27:* 139–148, 1924.

2. Wittkower, E. and Rodger, T. F.: Night Blindness, A Psychophysiological Study. Brit. Med. J., *2:* 571, 607, 1941.

C. *Xerophthalmia*

1. Bloch, C. E.: Clinical Investigation of Xerophthalmia and Dystrophy in Infants and Young Children (Xerophthalmia et Dystrophia Alipogentica). J. Hygiene, *19:* 283–304, 1921.
2. Blegvad, O.: Xerophthalmia, Keratomalacia and Xerosis Conjunctivae; with Bibliography. Am. J. Ophth., *7:* 89–117, 1924.
3. Blackfan, K. D. and Wolbach, S. B.: Vitamin A Deficiency in Infants; Clinical and Pathological Study. J. Pediat., *3:* 679–706, 1933.

D. *Phrynoderma*

1. Nicholls, L.: Phrynoderma: A Condition Due to Vitamin Deficiency. Indian Med. Gazette, *68:* 681–686, 1933; *69:* 241, 1934.
2. Nicholls, L.: Inspectional Value of Phrynoderma and Sore Mouth. Indian Med. Gazette, *70:* 14–15, 1935.
3. Frazier, C. N. and Hu, C. K.: Nature and Distribution According to Age of Cutaneous Manifestations of Vitamin A Deficiency: A Study of 207 Cases. Arch. Dermat. & Syph., *33:* 825–852, 1936.
4. Rao, M. V. R.: Histopathology of the Skin in Keratomalacia. Indian J. Med. Res., *25:* 39–44, 1937.
5. Rao, M. V. R.: Phrynoderma: A Clinical and Histopathological Study. Indian Med. Gazette, *73:* 461–462, 1938.
6. Frazier, C. N., Hu, C. K., and Chu, F. T.: Variations in the Cutaneous Manifestations of Vitamin A Deficiency from Infancy to Puberty. Arch. Dermat. & Syph., *48:* 1–14, 1943.

E. *Rickets*

1. Chick, H. et al.: Studies of Rickets in Vienna, 1919–22. Med. Res. Council Special Report Series 77. London, 1923, p. 230.
2. Weech, A. A. and Smith, M. S.: Anatomic Basis for Interpreting Roentgenograms in Rickets. Am. J. Dis. Child., *26:* 117–131, 1923.
3. Wimberger, H.: Klinisch-Radiologische Diagnostik von Rachitis, Skorbut und Lues Congenita im Kindesalter. Ergebn. d. inn. Med. u. Kinderh., *28:* 264–270, 1925.
4. Parsons, L. G.: The Bone Changes Occurring in Renal and Celiac Infantilism and Their Relationship to Rickets; Renal Rickets. Arch. Dis. Childhood., *2:* 1–25, 1927.
5. Park, E. A.: Blackader Lecture on Some Aspects of Rickets. Canad. Med. Assoc. J., *26:* 3–15, 1932.
6. Bromer, R. S.: Rickets. Am. J. Roentgenol., *30:* 582–589, 1933.
7. Cooley, T. B. and Reynolds, L.: The Interpretation of X-Ray Films in the Diagnosis of Rickets. J. Pediat., *10:* 743–747, 1937.
8. Park, E. A. and Eliot, M. M.: Rickets. *In* Brennemann, Joseph, Ed.: Practice of Pediatrics III, Chap. 29. Hagerstown, Md. W. F. Prior Co., 1937.

9. Albright, F., Butler, A. M., and Bloomberg, E.: Rickets Resistant to Vitamin D Therapy. Am. J. Dis. Child., *54:* 529–547, 1937.
10. Park, E. A.: Observations on the Pathology of Rickets with Particular Reference to the Changes at the Cartilage-Shaft Junctions of the Growing Bones (Harvey Lecture). Bull. New York Acad. Med., *15:* 495–543, 1939.
11. McCune, D. J., Mason, H. H., and Clarke, H. T.: Late Rickets with Glycosuria and Organic Acid Acidosis (Fanconi Type). Am. J. Dis. Child., *58:* 673, 1939.

F. *Hypoprothrombinemia*

1. Brinkhous, K. M., Smith, H. P., and Warner, E. D.: Plasma Prothrombin Level in Normal Infancy and in Hemorrhagic Disease of the Newborn. Am. J. Med. Sci., *193:* 475–480, 1937.
2. Dam, H. and Glavind, J.: Vitamin K in Human Pathology. Lancet, *1:* 720–721, 1938; Ugesk, f. Laeger, *100:* 248–250, 1938.
3. Butt, H. R., Snell, A. M., and Osterberg, A. E.: The Preoperative and Postoperative Administration of Vitamin K to Patients Having Jaundice. J. A. M. A., *113:* 383–389, 1939.
4. Kato, K. and Poncher, H. G.: Prothrombin in the Blood of Mature and Immature Infants as Determined by Micro-prothrombin Test. J. A. M. A., *114:* 749–753, 1940.
5. Poncher, H. G. and Kato, K.: Treatment of Hypoprothrombinemia Heamorrhagica Neonatorum (Hemorrhagic Disease of the Newborn) with Vitamin K. J. A. M. A., *115:* 14–17, 1940.
6. Brinkhous, K. M.: Plasma Prothrombin; Vitamin K. Medicine, *19:* 329–416, 1940.
7. Kark, R. and Souter, A. W.: Hypoprothrombinaemia and Avitaminosis-K in Man. Brit. Med. J., *2:* 190–194, 1941.
8. Butt, H. R. and Snell, A. M.: Vitamin K. Philadelphia and London. W. B. Saunders Co., 1941.

VII. *WATER-SOLUBLE VITAMINS*

A. *Beriberi* (*Infantile and Adult*)

1. Fraser, H. and Stanton, A. T.: An Inquiry Concerning the Etiology of Beri-beri. Lancet, *1:* 451–455, 1909.
2. Shattuck, G. C.: Relation of Beri-beri to Polyneuritis from Other Causes. Am. J. Trop. Med., *8:* 539–543, 1928.
3. Aalsmeer, W. C. and Wenckebach, K. F.: Herz und Kreislauf bei der Beriberi-Krankheit. Wien Arch. f. inn. Med., *16:* 193, 1929.
4. Vedder, E. B.: Beriberi. *In* Tice, Frederick, Ed.: Practice of Medicine IX. Hagerstown, Md. W. F. Prior Co., 1929.
5. Keefer, C. S.: Beriberi Heart. Arch. Int. Med., *45:* 1–22, 1930.
6. Shimazono, J.: B-Avitaminosis und Beriberi. Ergebn. d. inn. Med. u. Kinderh., *39:* 1–68, 1931.
7. Weiss, S. and Wilkins, R. W.: The Nature of the Cardiovascular Dis-

turbances in Vitamin Deficiency States. Tr. Assoc. Am. Physicians, *51:* 341–373, 1936.

8. Platt, B. S. and Lu, G. D.: Chemical and Clinical Findings in Beriberi, with Special Reference to Vitamin B Deficiency. Quart. J. Med., *5:* 355–373, 1936.
9. Weiss, S. and Wilkins, R. W.: The Nature of the Cardiovascular Disturbances in Nutritional Deficiency States (Beriberi). Ann. Int. Med., *11:* 104–148, 1937.
10. Weiss, S. and Wilkins, R. W.: Disturbance of the Cardiovascular System in Nutritional Deficiency. J. A. M. A., *109:* 786–793, 1937.
11. Bray, G. W.: Vitamin B. Deficiency in Infants; Its Possibility, Prevalence and Prophylaxis. Tr. Roy. Soc. Trop. Med. & Hyg., *22:* 9–42, 1928.
12. Hibbs, R. E.: Beriberi in a Japanese Prison Camp. Ann. Int. Med., *25:* 270–282, 1946.

B. *Ariboflavinosis*

1. Aykroyd, W. R. and Krishnan, B. G.: Stomatitis Due to Vitamin B_2 Deficiency. Indian J. Med. Res., *24:* 411–417, 1936.
2. Sebrell, W. H. and Butler, R. E.: Riboflavin Deficiency in Man. U. S. Pub. Health Rep., *53:* 2282–2284, 1938.
3. Sydenstricker, V. P., Geeslin, L. E., Templeton, C. M., and Weaver, J. W.: Riboflavin Deficiency in Human Subjects. J. A. M. A., *113:* 1697–1700, 1939.
4. Spies, T. D., Bean, W. B., Vilter, R. W., and Huff, N. E.: Endemic Riboflavin Deficiency in Infants and Children. Am. J. Med. Sci., *200:* 697–701, 1940.
5. Sydenstricker, V. P., Sebrell, W. H., Cleckley, H. M., and Kruse, H. D.: The Ocular Manifestations of Ariboflavinosis; Progress Note. J. A. M. A., *114:* 2437–2445, 1940.
6. Aykroyd, W. R. and Verma, O. P.: Superficial Keratitis Due to Riboflavin Deficiency. Indian Med. Gazette, *77:* 1–4, 1942.
7. Stannus, H. S.: Some Problems in Riboflavin and Allied Deficiencies (Lumleian Lectures). Brit. Med. J., *2:* 103, 140, 1944.

C. *Scurvy, Infantile (Barlow's Disease) and Adult*

1. Hess, A. F.: Subacute and Latent Infantile Scurvy. J. A. M. A., *68:* 235–239, 1917.
2. Hess, A. F.: Infantile Scurvy. *In* Abt, I. A., Ed.: System of Pediatrics II, Chap. 30. Philadelphia. W. B. Saunders Co., 1923.
3. Pelkan, K. F.: The Roentgenogram in Early Scurvy. Am. J. Dis. Child., *30:* 174–188, 1925.
4. Schwartz, A. B.: Epiphyseal Changes in the Diagnosis of Scurvy. Am. J. Dis. Child., *34:* 765–772, 1927.
5. Bromer, R. S.: The Roentgen-Ray Diagnosis of Infantile Scurvy. Am. J. Roentgenol., *19:* 112–125, 1928.
6. Mettier, S. R., Minot, G. R., and Townsend, W. C.: Scurvy in Adults;

Especially, the Effect of Food Rich in Vitamin C on Blood Formation. J. A. M. A., *95:* 1089–1093, 1930.

7. Kato, K.: Critique of the Roentgen Signs of Infantile Scurvy, with Report of Thirteen Cases. Radiology, *18:* 1096–1110, 1932.
8. Barlow, T.: On Cases Described as "Acute Rickets" Which Are Probably a Combination of Scurvy and Rickets, the Scurvy Being an Essential and the Rickets a Variable Element. Arch. Dis. Childhood, *10:* 223–252, 1935.
9. Park, E. A., Guild, H. G., Jackson, D., and Bond, M.: Recognition of Scurvy with Especial Reference to Early X-Ray Changes. Arch. Dis. Childhood, *10:* 265–294, 1935.
10. Jenovese, J. F., Osterberg, A. E., and Rynearson, E. H.: Role of Vitamin C in Addison's Disease. Proc. Soc. Exp. Biol. & Med., *44:* 335–339, 1940.
11. Fox, F. W., Dangerfield, L. F., Gottlich, S. F., and Jokl, E.: Vitamin C Requirements of Native Mine Laborers; Experimental Study. Brit. Med. J., *2:* 143–147, 1940.
12. Scarborough, H.: Deficiency of Vitamin C and Vitamin P in Man. Lancet, *2:* 644–647, 1940.
13. Bromer, R. S.: Roentgen-Ray Diagnosis of Infantile Scurvy. Am. J. Roentgenol., *19:* 112–125, 1928; *49:* 575–579, 1943.
14. Blitz, D.: Infantile Scurvy; Case Report with Follow-Up Roentgenogram of Pre-Existent Healed Scurvy. J. Pediat., *23:* 87–89, 1943.
15. McMillan, R. B. and Inglis, J. C.: Scurvy: A Survey of Fifty-three Cases. Brit. Med. J., *2:* 233–236, 1944.

VIII. *SPECIFIC AND COMBINED NUTRITIONAL DEFICIENCIES*

A. *Pellagra (Infantile and Adult)*

1. Stannus, H. S.: Pellagra in Nyasaland. Tr. Roy. Soc. Trop. Med. & Hyg., *5:* 112–119, 1911–12; *7:* 32–56, 1913–14.
2. Bloch, C. E.: Effects of Deficiency in Vitamins in Infancy; Caries of Teeth and Vitamins. Am. J. Dis. Child., *42:* 263–278, 1931.
3. Spies, T. D., Chinn, A. B., and McLester, J. B.: Severe Endemic Pellagra; Clinical Study of Fifty Cases, with Special Emphasis on Therapy. J. A. M. A., *108:* 853–857, 1937.
4. Sydenstricker, V. P. and Armstrong, E. S.: Review of 440 Cases of Pellagra. Arch. Int. Med., *59:* 883–891, 1937.
5. Trowell, H. C.: Pellagra in African Children. Arch. Dis. Childhood, *12:* 193–212, 1937.
6. Spies, T. D., Bean, W. B., and Stone, R. E.: The Treatment of Subclinical and Classic Pellagra. J. A. M. A., *111:* 584–592, 1938.
7. Cleckley, H. M., Sydenstricker, V. P., and Geeslin, L. E.: Nicotinic Acid in the Treatment of Atypical Psychotic States Associated with Malnutrition. J. A. M. A., *112:* 2107–2110, 1939.
8. Spies, T. D., Walker, A. A., and Woods, A. W.: Pellagra in Infancy and Childhood. J. A. M. A., *113:* 1481–1483, 1939.

9. Trowell, H. C.: Infantile Pellagra. Tr. Roy. Soc. Trop. Med. & Hyg., *33:* 389–404, 1940.
10. Field, H., Jr., Parnall, C., Jr., and Robinson, W. D.: Pellagra in an Average Population of Northern States. New England J. Med., *223:* 307–315, 1940.
11. Bean, W. B., Spies, T. D., and Blankenhorn, M. A.: Secondary Pellagra. Medicine, *23:* 1–77, 1944.
12. Bean, W. B., Spies, T. D., and Vilter, R. W.: Asymmetric Cutaneous Lesions in Pellagra. Arch. Derm. & Syph., *49:* 335–345, 1944.

B. *Addisonian Pernicious Anemia*

1. Minot, G. R. and Murphy, W. P.: Treatment of Pernicious Anemia by a Special Diet. J. A. M. A., *87:* 470–476, 1926.
2. Minot, G. R. and Murphy, W. P.: Treatment of Pernicious Anemia by a Special Diet. Blood, *3:* 8–21, 1948.
3. Haden, R. L.: Pernicious Anemia from Addison to Folic Acid. Blood, *3:* 22–31, 1948.
4. Bethell, F. H. and Sturgis, C. C.: The Relation of Therapy in Pernicious Anemia to Changes in the Nervous System; Early and Late Results in a Series of Cases Observed for Periods of Not Less than Ten Years, and Early Results of Treatment with Folic Acid. Blood, *3:* 57–67, 1948.

C. *Pernicious Anemia of Pregnancy*

1. Wills, L.: Studies in Pernicious Anemia of Pregnancy; Tropical Macrocytic Anemia as a Deficiency Disease, with Special Reference to the Vitamin B Complex. Indian J. Med. Res., *21:* 669–681, 1934.
2. Strauss, M. B.: Etiology and Treatment of Anemia in Pregnancy. J. A. M. A., *102:* 281–283, 1934.
3. Segerdahl, E.: Pernicious Anemia of Pregnancy; Clinical and Hematological Study. Acta. Med. Scandinav., *108:* 483–501, 1941.

D. *Exogenous Pernicious Anemia (or Extrinsic Factor Deficiency)*

1. Alsted, G.: Exogenous Pernicious Anemia. Am. J. Med. Sci., *197:* 741–750, 1939.

E. *Nutritional Macrocytic Anemia*

1. Groen, J. and Snapper, I.: Dietary Deficiency as a Cause of Macrocytic Anemia. Am. J. Med. Sci., *193:* 633–646, 1937.
2. Wills, L. and Evans, B. D. F.: Tropical Macrocytic Anemia: Its Relation to Pernicious Anemia. Lancet, *2:* 416–421, 1938.
3. Wills, L.: Pernicious Anemia, Nutritional Macrocytic Anemia, and Tropical Sprue. Blood, *3:* 36–56, 1948.

F. *Nutritional Pancytopenia*

1. Langston, W. C., Darby, W. J., Shukers, C. F., and Day, P. L.: Nutritional Cytopenia (Vitamin M Deficiency) in the Monkey. J. Exp. Med., *68:* 923–940, 1938.

G. *Sprue*

1. Castle, W. B. and Rhoads, C. P.: The Etiology and Treatment of Sprue in Puerto Rico. Lancet, *1:* 1198–1199, 1932.

2. Mackie, T. T., Miller, D. K., and Rhoads, C. P.: Sprue: Roentgenologic Changes in the Small Intestine. Am. J. Trop. Med., *15:* 571–589, 1935.
3. Castle, W. B., Rhoads, C. P., Lawson, H. A., and Payne, G. C.: Etiology and Treatment of Sprue; Observations on Patients in Puerto Rico and Subsequent Experiments on Animals. Arch. Int. Med., *56:* 627–699, 1935.
4. Hanes, F. M. and McBryde, A.: Identity of Sprue, Non-tropical Sprue and Celiac Disease. Arch. Ind. Med., *58:* 1–16, 1936.
5. Snell, A. M.: Tropical and Non-tropical Sprue (Chronic Idiopathic Steatorrhea): Their Probable Interrelationship. Ann. Int. Med., *12:* 1632–1671, 1939.

H. *Celiac Disease*

1. Parsons, L. G.: Celiac Disease (Rachford Memorial Lectures). Am. J. Dis. Child., *43:* 1293–1346, 1932.

I. *Idiopathic Steatorrhea*

1. Snell, A. M. and Camp, J. D.: Chronic Idiopathic Steatorrhea; Roentgenologic Observations. Arch. Int. Med., *53:* 615–629, 1934.
2. Thaysen, T. E. H.: Ten Cases of Idiopathic Steatorrhea. Quart. J. Med., (new series) *4:* 359–395, 1935.
3. Albright, F. and Stewart, J. D.: Hypovitaminosis of All Fat-Soluble Vitamins Due to Steatorrhea; Report of a Case. New England J. Med., *223:* 239–241, 1940.

J. *Kwashiorkor*

1. Suzman, M. M.: Clinical Aspects of Vitamin B Deficiency in South Africa. Clinical Proc., *1:* 205–231, 1944.

K. *Nutritional Gynecomastia*

1. Klatskin, G., Salter, W. T., and Humm, F. D.: Gynecomastia Due to Malnutrition. I. Clinical Studies. Am. J. Med. Sci., *213:* 19–30, 1947.
2. Salter, W. T., Klatskin, G., and Humm, F. D.: Gynecomastia Due to Malnutrition. II. Endocrine Studies. Am. J. Med. Sci., *213:* 31–36, 1947.

L. *Burning Foot Syndrome* (*Happy Foot Syndrome*)

1. Harrison, G. F.: Nutritional Deficiency, Painful Feet, High Blood Pressure in Hong Kong. Lancet, *1:* 961–964, 1946.
2. Simpson, J.: "Burning Feet" in British Prisoners-of-War in the Far East. Lancet, *1:* 959–961, 1946.
3. Glusman, M.: Syndrome of "Burning Feet" (Nutritional Melalgia) as a Manifestation of Nutritional Deficiency. Am. J. Med., *3:* 211–223, 1947.

M. *Nutritional Myasthemia Gravis of Prisoners of War*

1. Musselman, M. M.: Nutritional Diseases in Cabanatuon Camp. War Medicine, *8:* 325–332, 1945.

N. *Polyneuritis of Pregnancy*

1. Strauss, M. B. and McDonald, W. J.: Polyneuritis of Pregnancy; A Dietary Deficiency Disorder. J. A. M. A., *100:* 1320–1323, 1933.

2. Plass, E. D. and Mengert, W. F.: Gestational Polyneuritis. J. A. M. A., *101:* 2020–2023, 1933.

O. *Nutritional Polyneuritis*
  1. Minot, G. R., Strauss, M. B., and Cobb, S.: "Alcoholic" Polyneuritis, Dietary Deficiency as a Factor in Its Production. New England J. Med., *208:* 1244–1249, 1933.
  2. Strauss, M. B.: The Therapeutic Use of Vitamin B_1 in Polyneuritis and Cardiovascular Conditions. *In* The Vitamins, 193–202. Chicago. American Medical Association, 1939.
  3. Walshe, F. M. R.: Aetiology of Polyneuritis. Lancet, *1:* 33–35, 1941.

P. *Nutritional Amblyopia (Including Central Scotoma and Retrobulbar Neuritis)*
  1. Raman, T. K. and Abbu, C.: Lesions of the Optic Nerve in Vitamin B_1 Deficiency. J. Indian Med. Assoc., *10:* 417–422, 1941.
  2. Wilkinson, P. B. and King, A.: Amblyopia Due to a Vitamin Deficiency. Lancet, *1:* 528–531, 1944.

Q. *Nutritional Disturbances of Cranial Nerves*
  1. Spillane, J. D. and Scott, G. I.: Obscure Neuropathy in the Middle East; Report on 112 Cases in Prisoners-of-War. Lancet, *2:* 261–264, 1945.
  2. Spillane, J. D.: Nutritional Diseases of the Nervous System. Baltimore. Williams & Wilkins, 1946.

R. *Generally Useful References*
  1. Davidson, L. S. P. and Leitch, I.: Nutritional Anaemias of Man and Animals. Nutr. Abst. & Rev., *3:* 901–930, 1934.
  2. Mackie, T. T. and Pound, R. E.: Changes in the Gastro-intestinal Tract in Deficiency States, with Special Reference to the Small Intestine: Roentgenologic and Clinical Study of 40 Cases. J. A. M. A., *104:* 613–618, 1935.
  3. Spies, T. D., Vilter, R. W., and Ashe, W. F.: Pellagra, Beriberi and Riboflavin Deficiency in Human Beings: Diagnosis and Treatment. J. A. M. A., *113:* 931–937, 1939.
  4. Golden, R.: Abnormalities of the Small Intestine in Nutritional Disturbances: Some Observations on Their Physiologic Basis (Carman Lecture). Radiology, *36:* 262–286, 1941.

IX. *SOME DISEASES SUSPECTED OF BEING IN PART RELATED TO MALNUTRITION*

A. *Darier's Disease*
  1. Peck, S. M., Chargin, L., and Sobotka, H.: Keratosis Follicularis (Darier's Disease); A Vitamin A Deficiency Disease. Arch. Derm. & Syph., *43:* 223–229, 1941.
  2. Peck, S. M., Glick, A. W., Sobotka, H., and Chargin, L.: Vitamin A Studies on Cases of Keratosis Follicularis (Darier's Disease). Arch. Dermat. & Syph., *48:* 17–31, 1943.

B. *Acne Rosacea*
  1. Tulipan, L.: Acne Rosacea, A Vitamin B Complex Deficiency. Arch. Dermat. & Syph., *56:* 589–591, 1947.

C. *Hepatoses (Some Types, Including Alcoholic Cirrhosis)*

1. Patek, A. J., Jr.: Treatment of Alcoholic Cirrhosis of the Liver with High Vitamin Therapy. Proc. Soc. Exp. Biol. & Med., *37:* 329–330, 1937.
2. Connor, C. L.: Etiology and Pathogenesis of Alcoholic Cirrhosis of the Liver. J. A. M. A., *112:* 387–390, 1939.
3. Patek, A. J., Jr., and Post, J.: Treatment of Cirrhosis of the Liver by Nutritious Diet and Supplements Rich in Vitamin B Complex. J. Clin. Invest., *20:* 481–505, 1941.

D. *Wernicke's Encephalopathy*

1. Campbell, A. C. P. and Russell, W. R.: Wernicke's Encephalopathy; Clinical Features and their Probable Relationship to Vitamin B Deficiency. Quart. J. Med., *10:* 41–64, 1941.

E. *Purpura, Some Types*

1. Scarborough, H., and Stewart, C. P.: Effect of Hesperidin (Vitamin P) on Capillary Fragility. Lancet, *2:* 610–612, 1938.

X. *DISORDERS RELATED TO INGESTION OF SUBSTANCES, SOME TOXIC*

A. *Fluorosis*

1. Black, G. V. and McKay, F. S.: An Investigation of Mottled Teeth. Dental Cosmos, *58:* 129–156, 1916.
2. Smith, M. C., Lantz, E. M., and Smith, H. V.: The Cause of Mottled Enamel, a Defect of Human Teeth. Univ. Ariz. Ag. Exp. Sta. Tech. Bull., *32:* 253, 1931.
3. DeEds, F.: Chronic Fluorine Intoxication; A Review. Medicine, *12:* 1–60, 1933.
4. Dean, H. T.: Chronic Endemic Dental Fluorosis (Mottled Enamel). J. A. M. A., *107:* 1269–1273, 1936.

B. *Cobalt Polycythemia*

1. Barron, A. G. and Barron, E. S. G.: Mechanism of Cobalt Polycythemia; Effect of Ascorbic Acid. Proc. Exp. Biol. & Med., *35:* 407–409, 1936.

C. *Hypervitaminosis A*

1. Josephs, H. W.: Hypervitaminosis A and Carotinaemia. Am. J. Dis. Child., *67:* 33–43, 1944.

D. *Carotinaemia*

1. Stannus, H. S.: Hyperlipochromia; Carotinaemia, Xanthosis, Cutis. Internat. Clin., *1:* 146–163, 1929.
2. Almond, S. and Logan, R. F. L.: Carotinaemia. Brit. Med. J., *2:* 239–241, 1942.
3. Hoch, H.: The Effect of Prolonged Administration of Carotene in the Form of Vegetables on the Serum Carotene and Vitamin A Levels in Man. Biochem. J., *37:* 430–433, 1943.

E. *Hypervitaminosis D*

1. Thatcher, L.: Hypervitaminosis D. Lancet, *1:* 20–22, 1936.

2. Ross, S. G. and Williams, W. E.: Vitamin D Intoxication in Infancy. Am. J. Dis. Child., *58:* 1142–1143, 1939.
3. Freeman, S., Rhodes, P. S., and Yeager, L. R.: Toxic Manifestations Associated with Prolonged Ertron Ingestion. J. A. M. A., *130:* 197–202, 1946.

F. *Dicoumarol Poisoning*

1. Wright, I. and Prandoni, A.: Dicoumarin, 3,3′-methylene-bis-(4-hydroxycoumarin); Its Pharmacologic and Therapeutic Action in Man. J. A. M. A., *120:* 1015–1021, 1942.
2. Cahan, A.: Hemorrhage and Purpura Caused by Dicoumarin; Report of a Case. New England J. Med., *228:* 820–822, 1943.
3. Barker, N. W., Cromer, H. E., Hurn, M., and Waugh, J. M.: The Use of Dicoumarol in the Prevention of Post-Operative Thrombosis and Embolism, with Special Reference to Dosage and Safe Administration. Surg., *17:* 207–217, 1945.

G. *Lathyrism*

1. Anderson, L. A. P., Howard, A., and Simonsen, J. L.: Studies on Lathyrism. Indian J. Med. Res., *12:* 613–643, 1925.
2. Young, T. C. M.: A Field Study of Lathyrism. Indian J. Med. Res., *15:* 453–480, 1927.
3. Minchin, R. L. H.: Primary Lateral Sclerosis in South India; Lathyrism Without Lathyrus. Brit. Med. J., *1:* 253–255, 1940.

H. *Milk Intoxication*

1. Fehily, L.: Human-Milk Intoxication Due to B_1 Avitaminosis. Brit. Med. J., *2:* 590–592, 1944.

XI. *NUTRITIONAL DISTURBANCES RELATED TO INFECTION*

A. *Anemia of Infection with Diphyllobothrium Latum*

1. Bonsdorff, B. von: Pernicious Anemia Caused by Diphyllobothrium Latum in the Light of Recent Investigations. Blood, *3:* 91–102, 1948.

B. *Anemia of Chronic Infection*

1. Wintrobe, M. M. et al.: Anemia of Infection; Uptake of Radio-Active Iron in Iron-Deficient and in Pyridoxine-Deficient Pigs Before and After Acute Inflammation. J. Clin. Invest., *26:* 103–113, 1947.

C. *The Dysenteries*

1. Farah, N.: Enteric Fever Treated with Suprarenal Cortex Extract and Vitamin C Intravenously. Lancet, *1:* 777–779, 1938.
2. Manson-Bahr, P.: The Dysenteric Disorders; the Diagnosis and Treatment of Dysentery, Sprue, Colitis and Other Diarrheas in General Practice. Baltimore. Williams & Wilkins, 1939.

XII. *NUTRITIONAL DISTURBANCES RELATED TO INJURIES*

A. *Wound Healing*

1. Zintel, H. A.: The Healing of Wounds. Surgical Clinics of North America. Philadelphia. W. B. Saunders Co., 1946. P. 1404–1415.

B. *The Catabolic Reaction*

1. Browne, J. S. L., Schenker, V., and Stevenson, J. A. F.: Some Metabolic Aspects of Damage and Convalescence. J. Clin. Invest., *23:* 932, 1944.

BIBLIOGRAPHY

1. Adamson, J. D., Jolliffe, N., Kruse, H. D., Lowry, O. H., Moore, P. E., Platt, B. S., Sebrell, W. H., Tice, J. W., Tisdall, F. F., Wilder, R. M., and Zamecnik, P. C.: Medical Survey of Nutrition In Newfoundland. Canad. Med. Assoc. J., *52:* 227–250, 1945.
2. Adolph, E. F.: The Physiology of Man in the Desert. New York. Interscience Publishers, 1947.
3. Bean, W. B.: Cutaneous Arterial Spider; A Survey. Medicine, *24:* 243–331, 1945.
4. Berryman, G. H. and Chatfield, C.: A Short Method of Calculating the Nutritive Value of Diets. J. Nutrition, *25:* 23–37, 1943.
5. Berryman, G. H. and Howe, P. E.: A Short Method of Calculating the Nutritive Value of Diets (Concluded): J. Nutrition, *27:* 231–240, 434, 1944.
6. Bessey, O. A.: Proceedings of Conference on Methods of Evaluating Nutritional Status of Mothers, Infants and Children. Detroit, Michigan. Research Laboratory of the Children's Fund of Michigan, 1947, p. 53.
7. Borsook, H.: Effects of Vitamin Supplementation on Absenteeism, Turnover and Personnel Rating. Milbank Mem. Fund. Quart., *23:* 113–160, 1945.
8. Castle, W. B.: General Considerations in Vitamin Deficiencies. *In* Anaemias and Vitamin Deficiencies. Melbourne, Australia. Brown Prior, Anderson Pt., 1939. P. 101–119.
9. Crandon, J. H., Lund, C. C., and Dill, D. B.: Experimental Human Scurvy. New England J. Med., *223:* 353–369, 1940.
10. Dann, W. J. and Darby, W. J.: Appraisal of Nutritional Status (Nutriture) in Humans, with Especial Reference to Vitamin Deficiency Diseases. Physiol. Rev., *25:* 326–346, 1945.
11. Getz, H. R.: Nutrition and Tuberculosis. Nutrition Rev., *5:* 97–98, 1947.
12. Haldane, J. S. and Priestley, J. G.: Respiration. New Haven. Yale University Press, 1935.
13. Harris, Seale, and Harris, Seale, Jr.: Clinical Pellagra. St. Louis. C. V. Mosby Co., 1941.
14. Holt, L. E., Jr.: The B Vitamins and Certain Problems They Present to the Practicing Physician. Pennsylvania Med. J., *46:* 451–458, 1943.
15. Johnson, R. E., Darling, R. C., Forbes, W. H., Brouha, L., Egana, E., and Graybiel, A.: The Effects of a Diet Deficient in Part of the Vitamin B Complex Upon Men Doing Manual Labor. J. Nutrition, *24:* 585–596, 1942.
16. Johnson, R. E. and Kark, R. M.: Feeding Problems in Man as Related to Environment. Chicago. Quartermaster Food and Container Institute for the Armed Forces. 1946.
17. Johnson, R. E. and Kark, R. M.: Environment and Food Intake in Man. Science, *105:* 378–379, 1947.
18. Jolliffe, N.: Conditioned Malnutrition. J. A. M. A., *122:* 299–306, 1943.
19. Jolliffe, N.: The Clinical Signs of Malnutrition. Quarterly Bull., Dept. of Health, New York, June 1947.
20. Jolliffe, N. and Most, R. M.: Appraisal of Nutritional Status. Vitamins & Hormones, *1:* 59–107, 1943.
21. Keys, A., Henschel, A., Taylor, H. L., Mickelsen, O., and Brozek, J.: Experimental Studies on Man with a Restricted Intake of the B Vitamins. Am. J. Physiol., *144:* 5–42, 1945.
22. Kark, R. M., Aiton, H. F., Pease, E. D., Bean, W. B., Henderson, C. R., Johnson, R. E., and Richardson, L. M.: Tropical Deterioration and Nutrition. Medicine, *26:* 1–40, 1947.
23. Kark, R. M., Doupe, J., Aiton, H. F., and Pease, E. D.: Nutrition, Environment and Physical Fitness. J. Trop. Med. & Hyg., *49:* 103–107, 1946.
24. Kark, R. M., Croome, R. R. M., Cawthorpe, J., Bell, D. M., Bryans, A., MacBeth, R. J., Johnson, R. E., Consolazio, F. C., Poulin, J. L., Taylor, F. H. L., and Cogswell, R. C.: Observations on a Mobile Arctic Force. J. Applied Physiol., *1:* 73–92, 1948.
25. Kraut, H. A. and Muller, E. A.: Caloric Intake and Individual Output. Science, *104:* 495–497, 1946.
26. Kruse, H. D.: Medical Evaluation of Nutritional Status: IV. The Ocular Manifestation of Avitaminosis A, with Especial Consideration of the Detection of Early Changes by Biomicroscopy. U. S. Pub. Health Rep., *56:* 1301–1324, 1941.
27. ——: Medical Evaluation of Nutritional Status. Milbank Mem. Fund Quart., *19:* 207, 1941.

28. ——: The Gingival Manifestations of Avitaminosis C, with Especial Consideration of the Detection of Early Changes by Biomicroscopy. Milbank Mem. Fund Quart., *20:* 290-323, 1942.
29. ——: The Lingual Manifestations of Aniacinosis, with Especial Consideration of the Detection of Early Changes by Biomicroscopy. Milbank Mem. Fund Quart., *20:* 262–289, 1942.
30. LADELL, W. S. S., WATERLOW, J. C., AND HUDSON, M. F.: Desert Climate, Physiological and Clinical Observations. Lancet, *2:* 491, 527, 1944.
31. MEIKLEJOHN, A. P.: The Diagnosis and Treatment of Nutritional Deficiency. New England J. Med., *222:* 760–765, 1940.
32. PIJOAN, M. AND LOZNER, E. L.: The Physiological Significance of Vitamin C in Man. New England J. Med., *231:* 14–21, 1944.
33. SCHNEIDER, H. A.: Nutrition and Resistance to Infection: The Strategic Situation. Vitamins & Hormones, *4:* 35–70, 1946.
34. SEBRELL, W. H. AND BUTLER, R. E.: Riboflavin Deficiency in Man (Ariboflavinosis). U. S. Pub. Health Rep., *54:* 2121–2131, 1939.
35. STEWART, C. B. AND MANNING, G. W.: Detailed Analysis of Electrocardiograms of 500 RCAF Aircrew. Am. Heart J., *27:* 502–523, 1944.
36. STUART, H. C. AND MEREDITH, H. V.: Use of Body Measurements in the School Health Program. Part I. General Considerations and the Selection of Measurements. Am. J. Pub. Health, *36:* 1365–1373, 1946.
37. ——, ——: Ibid. Part II. Methods to be Followed in Taking and Interpreting Measurements and Forms to be Used. Am. J. Pub. Health, *36:* 1373–1386, 1946.
38. MEREDITH, H. V. AND STUART, H. C.: Ibid. Part III. Supplementary Note Supplying Measurement and Rating Equivalents for Thickness of Skin and Subcutaneous Tissue Below Left Scapula and Above Left Ilium. Am. J. Pub. Health, *37:* 1435–1438, 1947.
39. SWANSON, C.: The Differential Diagnosis of the Skin Manifestations in Pellagra from Other Dermatoses. South. Med. J., *9:* 117–123, 1916.
40. SYDENSTRICKER, V. P., GEESLIN, L. E., TEMPLETON, C. M., AND WEAVER, J. W.: Riboflavin Deficiency in Human Subjects. J. A. M. A., *113:* 1697–1700, 1939.
41. WETZEL, N. C.: Physical Fitness in Terms of Physique, Development and Basal Metabolism. J. A. M. A., *116:* 1187–1195, 1941.
42. WISING, P. J.: Monosymptomatic Isolated Riboflavin Deficiency (Ariboflavinosis) in A Human Subject. Acta. Med. Scandinav., *116:* 288–293, 1944.
43. WOLF, S.: Effects of Attitude and Conditioning on Action of Chemical Agents in Human Subjects. The Pharmacology of Placebos. Proc. Am. Soc. Clin. Invest., 40th Annual Meeting, May 3, 1948. P. 45.

SECTION V

THE ROLE OF SURVEYS IN COMMUNITY NUTRITION PROGRAMS

PAGE
Introduction 115
Types of Survey 116
  The survey of nutrition services available in a community 117
  The survey of food supplies 117
  The survey of dietary practices 118
    Individual dietary history 118
    Individual food intake record 119
    Family or institutional dietary surveys 119
  The survey of factual knowledge of nutrition 120
  The survey of nutritional status of individuals 120
  The survey to evaluate educational methods 120
Examples of surveys 121
Conclusion 124
Bibliography 124

INTRODUCTION

Since the beginning of public health work it has been recognized that, to be effective, a plan of action must be based on the actual situations of community life. The survey constitutes the means for obtaining the facts which describe these situations. In the early years of "nutrition work" surveys were neither as extensive nor as elaborately organized as those mentioned in the preceding papers. To secure information the workers had to use whatever means were at their disposal. A "survey" might have been nothing more than an oral questioning of club members in a rural area, but the answers indicated the need for more home gardens. Or it might have been a cursory inspection of children's lunches brought from home which demonstrated the necessity for improving them. The facts obtained from such observations, however elementary, guided the early workers in formulating plans of action.

During recent years, with the expansion of community nutrition services, there has been an increasing interest in the nutritional survey and the techniques for conducting it. Both official and voluntary health agencies recognize that the data obtained will eliminate to some extent the opportunism which has characterized many nutrition programs by directing their work into the areas where there is the greatest need. After an interval of observation or endeavor, the survey may be repeated to check the original observations or to evaluate whatever attempt has been made to change or to modify the nutritional aspects of community health. The survey has the additional advantage of motivating action. It is a commonplace that people are interested in what applies to themselves as individuals or in work to which they have contributed. When a survey is made locally, members of a community usually participate either as subjects or as volunteers assisting the technical personnel, and quite naturally they are interested in the results. Considered solely from the standpoint of motivating action, the nutrition survey easily justifies itself.

In organizing the survey, there are several factors affecting the total food environment which are important to consider inasmuch as they will influence whatever action program is to be undertaken subsequently. In the previous papers, these factors have been considered in discussions of the selection of samples and the interpretation of results. They will be reconsidered as they relate to the content of this paper.

The *season of the year* may cause a wide variation in diets for a given area. Data obtained in the early fall when garden produce is abundant and cheap usually give a very favorable picture, especially for people living on farms and in small towns. However, if the survey is repeated in the late spring, the diets may show marked inadequacies. The *geographical location* determines in part what foods are available in a given market. Accessibility to railways or highways influences the amount of food imported by a given community. A survey of food supplies or practices in one area of a county or state may be of little use in planning a program in another area unless the same variety of foods is available in each. Any given *occupational group* may have its individual food practices which will require special consideration in planning a community program. If the dietary findings from such a specialized group are included with those for the total working population, then the particular needs of that group may be overlooked. The same observation may be made with reference to the presence of one or more *national groups* in the sample. A school in one of the border states could have children of both Mexican and American parents, with each group adhering to its traditional diet. If the dietary records for both groups are reported in one set of figures, neither dietary pattern will be properly evaluated and the results will be misleading. An educational program based on such erroneous data will not be realistic and can result only in failure.

A nutrition survey of a community must also take into account the *economic status* of the subjects. Buying power determines to an appreciable extent the possibility of obtaining an adequate diet. The data of a survey are more useful if they are reported for several levels of income. A survey may also be concerned with the dietary practices of groups which are more or less homogeneous with respect to their *physiological status*, i.e., children in the primary school or adolescent boys and girls. If data are obtained from these sub-groups, an educational program prepared for their benefit will be adapted to the physiological needs and the psychological capacities of the group in question.

A detailed description of the *cultural environment* of the survey subjects is useful in modifying the approach and content of a nutrition program. Some of the techniques used by the social anthropologists in collecting data on attitudes toward food could with profit be incorporated in a survey of dietary practices.

TYPES OF SURVEY

There are several types of survey which are applicable to the purpose of determining community needs. The selection of the one to be used will depend on the nature of the information desired and on the facilities and funds available. The following types of survey will be discussed:

1. The survey of nutrition services available in a community.

2. The survey of food supplies.
3. The survey of dietary practices.
4. The survey of factual knowledge of nutrition.
5. The survey of the nutritional status of individuals (by physical examination and chemical tests).
6. The survey to evaluate educational methods.

1. *The survey of nutrition services available in a community.*—When a local group or agency wants to organize a nutrition service, the preliminary step in planning should be a careful review of the nutrition activities already existing in the community. If it is done properly, such a review will be, in effect, a survey. The advisory committee of the agency may appoint a subcommittee with both lay and professional representation to be responsible for the survey. The objectives will be to appraise the worth of current activities in the field of nutrition, to eliminate overlapping services, and to disclose unmet needs. During the war, the American Red Cross developed a form entitled "Survey of What Your Community Is Doing for Better Nutrition" to assist its chapters in planning their nutrition programs (1). While the items of the form refer to agencies and activities current in 1942, it is still useful as a list of community enterprises which should be appraised before a new program is undertaken.

Occasionally, the large urban centers invite a specialist to study their resources in the fields of health and welfare. A thorough-going review of the activities of all agencies usually covers those pertaining to nutrition. The recent "Survey of Health, Welfare, and Recreation Needs and Services of Springfield, Massachusetts" (2) directed by Dr. C. E. A. Winslow, includes an evaluation of the nutrition program in the Springfield area as related to the total health needs of the community.

2. *The survey of food supplies.*—The discussion here is limited to the crude survey which could be undertaken by a local nutrition committee or even a student group working under the leadership of a trained person, i.e., health officer, extension agent, nutritionist, or teacher. Even though it gives only a rough approximation of the condition of the local food supply, such a survey is useful in keeping the planning of a community program within the realities of a local situation.

A survey of food supplies may be concerned both with the quantity of food available for consumption and with its quality. Roughly, the quantity is equal to the food grown locally plus the food imported, minus that which is exported. This quantity may be compared with the amounts which would be required if each person in the community were to receive, for example, a minimum adequate diet. Or the quantity of available food may be divided by the number of consumer units. If the supply of any nutritionally important food appears to be insufficient, the reasons can be investigated and whatever educational program is in progress or in the planning stage will take account of the shortage. An adequate supply of a particular food does not mean that it will be equally distributed among all the members of the community. The distribution will be determined by differences in buying power and by individual preferences.

A rough check on how the food supply is being distributed throughout a given population may be made by a survey of buying practices in the different parts of the area. By consulting the food dealers, it is possible to learn not only what nutritionally important foods are purchased in a given district but how these purchases are affected by price changes. This kind of survey repeated periodically by volunteers can furnish rough data which will keep an educational program in line with the actual food situation.

A survey of the food supply in a food-producing area may include information on the disposition of surplus foods. If the surpluses are being wasted and either education or concerted action is the answer to a more efficient utilization, then a problem is posed for the nutrition service of that community. It frequently happens that nutritionally important foods are exported in quantities that leave the community with an insufficient supply, or occasionally such foods are turned to non-food uses. Whatever group is planning a community nutrition program should be aware of these facts.

The sources of information regarding the quantitative aspects of the food supply will vary in different communities. Wholesale and retail grocers, the dairy companies, the county extension agent, the Chamber of Commerce, and the State departments of agriculture are some of the agencies which can furnish pertinent facts.

Data describing the quality of the food supply are obtainable from at least two sources: the State or local departments of health, and the colleges and universities in the area. The health departments, both of the State and of the district, are responsible for the enforcement of ordinances which regulate the sanitation of milk and food. They have information regarding the quality of the milk supply and the sanitary aspects of food handling. The laboratories of the State colleges and universities usually have projects for investigating the nutritive quality of foods grown locally. Soils, climatic conditions, and the varieties of a particular species of food will modify nutritive values, and the degree to which these values differ from those in the standard food table should be taken into account in planning the subject matter to be used in the nutrition program of a given community.

3. *The survey of dietary practices.*—A survey of dietary practices may be made in several ways. It may consist of an investigation of the food practices of individuals or of a group of individuals eating together as a group, such as the family. Or it may be a description of the folkways of preparing and valuing food with no consideration for the behavior of individuals. The section on "Dietary Surveys and Their Interpretation" has defined the principal types of dietary survey. The contribution of this paper will be to present a few additional comments with a relisting of the various forms in order to clarify the ensuing discussion.

a. *Individual dietary history.*—A dietary history includes an account of the foods usually eaten during the course of the day, recorded in meal patterns and between-meal feedings. This is cross-checked with a report of the amounts and frequency with which each of the different food groups are used habitually (3). The history is supposed to approximate the typical food intake over a given period of time. Supplementary information is also obtained regarding social, environmental, economic, and psychological factors which may influence the individual's food habits. For this purpose, questions are asked about occupation, place where meals are eaten, facilities for food preparation, expenditures for food, and food preferences and aversions and the reasons for them.

The term nutritional history is often used interchangeably with dietary history. However, a nutritional history should represent a physical and biochemical appraisal of the nutritional status of the individual, combined with a dietary history.

b. *Individual food intake record.*—In public health practice the food intake record consists of a report of the food eaten either for the whole day or for a given meal as at breakfast or lunch. It may be furnished by the subject, who has been given a specially prepared form and instructions for reporting kinds and amounts of food eaten. The food record may also be obtained by a trained worker through an interview with the subject. In these two cases the food record is only an approximation of the amounts of food eaten. For a more accurate record the subject may be asked to weigh out all the food eaten or the investigator may do it for him. This procedure increases to a considerable extent the accuracy of the report by furnishing more exact information regarding amounts. However, it is a tedious procedure and requires some selection of subjects in order to find cooperative ones. It also creates an artificial situation in that the individual may eat more or less than desired to save himself the trouble of weighing the food.

Food intake records may be kept for one, three, seven, or more days at a time. As a matter of fact, there is at present no agreement among investigators as to the number of days which can give a representative picture of the typical food intake. There is good argument for repetition to eliminate the effect of seasonal variations. It is generally agreed that children under ten or eleven years of age are not usually satisfactory subjects. They cannot remember all that they have eaten nor can they record amounts of food with any degree of accuracy.

The findings from food intake records may be evaluated in two ways:

(1) Qualitative: a record of the intake of food groups, i.e., green leafy vegetables, citrus fruit, milk, etc.

(2) Quantitative: a determination of the nutritive value, i.e., number of calories, grams of protein, etc., either by actual analysis or by calculation using food tables.

Usually the first method is preferred. There is some controversy about the advisability of applying the second method to the evaluation of the data other than the weighed intake record, since there is always a question of the accuracy of the reports of the food eaten.

c. *Family or institutional dietary surveys.*—This type of survey of food practices has been adequately discussed in the section on "Dietary Surveys and Their Interpretation." The following comments refer to the practicability of this type of survey as a means of determining the dietary practices of a sample of the community.

For purposes of planning a community nutrition program, a survey of food practices should be planned to furnish information on methods of food preparation and the prevalent attitudes toward specific foods. A study of this nature usually is not undertaken as a separate project. The social anthropologist includes such observations in his study of a particular cultural group. The nutrition worker may obtain these data in conjunction with the dietary history or the food purchase study.

An investigation of food preparation methods will bring to light practices and prejudices which may be salutary or detrimental to good nutrition. A survey of food practices of families in Lubbock, Texas (4) disclosed the rather general use of "pot liquor." This is a desirable practice since the water in which vegetables are cooked often contains significant amounts of minerals and vitamins. Or the information obtained from diet histories may disclose a general custom of overcooking of vegetables or the soaking of foods "to remove poisons," practices whose correction will need to be taken into account in planning an educational program.

Different cultures or sub-groups within a given culture may have specific attitudes toward foods. For instance, among some groups milk may be considered a food solely for children, most of the meat allowance may be saved for the working man, the use of dark bread may be a measure of social status, etc. The "Manual for the Study of Food Habits" (5) is a guide for those workers who wish to plan surveys which take into account the social and cultural factors determining food practices.

4. *The survey of factual knowledge of nutrition.*—The survey of factual knowledge may have two purposes: 1) to determine the content of subject matter to be used in a particular situation; 2) to measure the effectiveness of a method in presenting facts. Before planning the content of class material or of audio-visual aids for use with a given group (housewives, industrial workers, etc.) it is advisable to know the extent to which the group is familiar with the principles of nutrition and their application in the choice of food. Questionnaires, quizzes, true and false or multiple choice tests are frequently used to get the information. The repetition of a test serves as a means of measuring the effectiveness of a particular technique in conveying facts. The results may also indicate a need for modifying either the subject matter or the method of presentation. Tests of factual knowledge usually stimulate an interest in the subject matter of nutrition but they cannot be considered a reliable index of the degree to which knowledge has influenced nutritional behavior.

5. *The survey of nutritional status of individuals.*—This type of survey has been ably discussed in the preceding sections. Few communities have the facilities or funds for making such detailed medical and biochemical studies. However, physicians can include in the routine physical examination some few items which have significance in appraising the nutritional condition of the individual patient. If this were done, a review of the case records in health centers, hospitals, schools, and the offices of private practitioners would give a clue to the incidence of some nutritional syndromes in the community.

6. *The survey to evaluate educational methods.*—A survey may be used to measure the effectiveness of a specific educational technique or a combination of several. To evaluate one or more techniques, a preliminary survey must be made. Any one of the types of survey previously discussed may be used, i.e., a study of food supplies, dietary practices, factual knowledge of nutrition, or nutritional status of a group of individuals. Then one or more educational methods are introduced to the community or to a selected group within it. After a given period of time the same survey is repeated. Any change in dietary knowledge, attitudes, practices, or nutritional status may be interpreted, with reservations, to be the result of the educational activities. Applying this procedure to test the effectiveness of one special technique

is practically impossible even under well controlled conditions, for too many factors are involved. For instance, if one wishes to know the effectiveness of a pamphlet, poster, or talk, it would be difficult to rule out the effect of other factors, such as the radio, talks with neighbors, or magazine articles, to which the individual may have been exposed during the same period.

EXAMPLES OF SURVEYS

The authors have reviewed several nutrition and dietary surveys done in the United States over a period of 30 years. Dating from the earliest papers of Goldberger to the present time, the surveys fall into two categories. For the first 20 years they were concerned almost solely with food consumption. A large number of surveys, published in bulletins of the agricultural experiment stations, have to do with the dietary practices of families living in rural areas. Beginning in the late thirties and especially during the present decade the surveys have assumed a different character. Now the greater number are concerned with investigating the prevalence of nutritional deficiencies by physical and biochemical methods and with determining their relationship to the dietary practices of the people.

If these surveys are considered with regard to remedial or preventive programs based on the findings, the results are surprisingly small. It could be concluded on the basis of published reports that almost no surveys disclosing unfavorable conditions were followed by an educational program designed to remedy them. In spite of the lack of printed evidence, it is common knowledge among community workers that this is not always the case. The surveys made by the agricultural experiment stations often were used by the extension agents in planning programs of food production for the farmer, or they served as a guide for education of the farmer's wife in food selection, menu planning, etc. Or we can consider the studies which relate the pregnant woman's diet to her obstetrical course and to the condition of her infant at birth and during the neonatal period. Even though the correlation between a poor diet and an unfavorable obstetrical course is not invariably a positive one, nevertheless the results of these studies have aroused a general concern among clinicians to the point where dietary advice for the pregnant woman is coming to be considered an essential part of good prenatal care. The public health agencies have drawn heavily on these studies and surveys in planning their prenatal services and in preparing educational material dealing with the diet during the prenatal and lactating periods.

A similar observation could be made of the surveys of the nutritional condition of children in relation to their food intake. While no mention is made of how the resulting data have been applied, it is known that school systems, health agencies, and commercial concerns have used the data in planning programs of nutrition education for children.

Following are a few examples of surveys in which it is implied or stated explicitly that the data were used in some manner as the basis for a program for nutritional improvement.

One community has used a survey of food purchases as the means of evaluating its nutrition education program. Young (6) reports the cooperation of 16 wholesale food concerns and 98 retail grocers of Richmond, Virginia, in replying to questionnaires which asked for information regarding the sales of protective foods. Volunteers from the Housewives' League distributed the questionnaires before the beginning of the nutrition education program and again 6 months later. An experimental area was selected and the rest of the city served as a control. Although there was a city-wide gain in the sales of protective foods during the 6-month period, it was more marked in the experimental area where considerable individual and group instruction in nutrition had been given.

The use of the dietary survey to arouse interest in community nutrition programs is described by Feldman and Kaiser (7). The survey was planned and completed by the nutrition committees of 21 counties in Illinois. Two types of survey form were used. One was a 24-hour food record, the second a 1- to 7-day check list of "basic seven" foods. Both were filled out by groups of school children. The results proved to the cooperating communities that there was a great need for nutrition education. They also demonstrated which foods were most often lacking in the diet. At the time this article was published, one county repeated the survey as a means of evaluating the results of an intensive nutrition program. An increased consumption of all the "basic seven" foods except meat, fish, poultry, and potatoes was reported. In addition, the findings were useful to the State and county nutrition committees in planning their program of work. "A Suggestive Guide for Teaching Nutrition in Illinois Elementary Schools" was prepared by the State committee and distributed to the schools by local groups. Special emphasis was placed on coordinating the nutrition program in the schools with a similar one for adults.

In New York City, Downes and Baranovsky tested the effect of nutrition teaching by the public health nurses on the food habits of 60 tuberculous families in the Harlem area (8). They made a preliminary survey of the consumption of protective foods during a 7-day period and the amount of money spent for food by each of the families. The same record was obtained subsequently at monthly intervals over a total of 6 months; meanwhile, the nurses were giving special nutrition instruction to the families. A year after the special teaching began, the families were revisited. The workers found a significant increase in the use of protective foods. It was concluded that this special nutrition teaching was a feasible plan for programs of public health nursing and that it accomplished noteworthy results.

The Food Supply Division of the Institute of Inter-American Affairs is responsible for an interesting study, "Paraguayan Rural Life—Survey of Food Problems" (9). This survey was conducted in the Piribebuy area of Paraguay. It considers the total factors which may influence the nutritional condition of a people—its history, climate, geography, racial stock, soil condition, culture, etc. Reh, who supervised the study, used an adaptation of the food record method described by Stiebeling for surveying the dietary practices of families. Recipes were carefully compiled as to ingredients and manner of preparation. The report describes taboos on food, their prestige values, and what foods are used especially for festive occasions. The collection of data concerning the total food environment is worthy of note. If this method were used more often by investigators, it might result in a much-needed respect for dietary folkways. From this study of the area, the inhabitants, and their food practices was drawn a suggested program for improving the food supply and for educating the people in its proper use.

There are some excellent studies to illustrate the use of the dietary survey in planning for nutrition teaching in primary and secondary schools. Bosley (10) reports using a 3-day record of food consumed by 9- to 11-year-old children as a basis for determining the kind of information to be taught. A similar study by Lockwood (11) takes into account the seasonal fluctuations in food intake by obtaining records at three different intervals during the school year. As a part of a research project in nutrition education, Whitehead (12) collected 7-day food records and made an evaluation of the adequacy of the diets. McHenry (13) obtained some valuable data on the health status and food habits of school children in a suburb of Toronto. A thorough medical examination, a dental inspection, records of food intake for 7-day periods, a questionnaire on food likes and dislikes, and a home visit to determine health conditions were all parts of the study. The data emerging from these surveys constituted the foundation for planning teaching units based on children's needs; the same data were used as groundwork for programs of in-service training of teachers. Moreover, since the general dietary pattern of a group of school children probably reflects the food habits of their families, the results of these surveys also were used in concurrent programs of nutrition education for adults.

The school lunch may serve as a means for studying the incidence of undesirable food habits and the extent to which they may be corrected by education. Some years ago the National Dairy Council made a survey of the lunches eaten by the children in a school cafeteria in Akron, Ohio (14). Only 8 per cent of the children had lunches which were considered nutritionally adequate. At the end of a 7-month program of teaching nutrition in the school, the percentage was increased to 72.

Vaughn (15) used a questionnaire as a means of surveying the nature of the facts about foods and nutrition which were known to a group of mothers attending a well child conference. On the basis of the answers, she planned a series of exhibits illustrating simple nutritional principles. The mothers were divided into experimental and control groups and the exhibits were presented at the conferences attended by the former. After an interval both groups were retested. The answers given by the mothers in the experimental group showed that the exhibits had been effective as a means of presenting facts.

Evaluation of a general program of nutrition education or of a specific method has been implicit in several of the surveys cited above (6, 7, 8, 15). There are a few examples of surveys set up definitely for the purpose of evaluating certain educational techniques. Radke and Klisurich (16) made a preliminary survey to determine the amount of milk, both fresh and canned, being used weekly by a group of housewives of low income level. The next step was to provide half the group with a lecture on nutrition which emphasized the role of milk in the well-balanced diet. The other half of the group participated freely in a discussion on the same subject and resolved by a unanimous vote to include more milk in the family diet. Follow-up surveys were made at intervals of two and four weeks. The individuals who had participated in the group decision were using more milk than those who had listened to the lecture. Radke and Caso (17) made a survey of the lunches eaten at school by a large group of junior high school pupils. The same educational techniques of lecture and discussion-decision were tested. The classrooms where the discussion-decision method was tried showed the most marked improvement in their lunch habits.

A publication of the Bureau of Agricultural Economics entitled "Homemakers' Acceptance of Nutrition Information in an Urban Community" (18) is an important contribution to the study of the effectiveness of educational programs as measured by levels of nutrition information. It reports the results of 400 personal interviews with housewives. The survey of levels of nutrition information was compared with a similar survey made four years earlier. The results indicated "that no larger proportion of homemakers has adequate information now than in 1943." The second part of the survey was concerned with analyzing the effectiveness of various media used in the dissemination of nutrition information and the third part with ascertaining the motivating factors which can be used in educational programs to promote a wider use of information on foods and nutrition among homemakers. Most homemakers said they got more of their ideas on food and nutrition from newspapers and magazines than from radio, pamphlets, or classes. They also said that a wider use of nutrition information could be motivated by pointing out that the foods they should eat are important for health, for stamina and longevity, and for the growth of their children.

A detailed "Guide" for community nutritionists is available (19). It was prepared at the request of community nutritionists and consists of a compilation of specific suggestions concerning community nutrition programs. It considers problems of organization, administration, and techniques as they relate to community nutrition programs. It also discusses types of nutrition surveys applicable to the community.

CONCLUSION

Nutrition surveys are helpful in planning community educational programs. There are many types of survey which may be used, depending on the information desired and the facilities, personnel, and funds available for making the survey. All have as their ultimate aims to ascertain need, to suggest corrective measures, to motivate the community to action for improved health, and to aid in the periodic evaluation of the program.

BIBLIOGRAPHY

1. Survey on What Your Community Is Doing for Better Nutrition, Supplement No. 13, The American National Red Cross, October, 1942.
2. Survey of Health, Welfare and Recreation Needs and Services—Community Chest Area—Springfield, Massachusetts; Section II. Protection and Promotion of Health. Community Council, Springfield, Mass.
3. Burke, B. S.: The Dietary History as a Tool in Research. J. Am. Dietetic Assoc., *23:* 1041–1046, 1947.
4. Drake, P., and Lamb, M. W.: Study of the Dietary and Food Practices of 63 Families in Lubbock, Texas. J. Am. Dietetic Assoc., *20:* 528–529, 1944.
5. Manual for the Study of Food Habits. Bull. 111, Committee on Food Habits, National Research Council, Washington, D. C., 1945.

6. YOUNG, A.: A Method for the Evaluation of a Community Nutrition Program. J. Am. Dietetic Assoc., *19:* 420–427, 1943.
7. FELDMAN, A. YOUNG, AND KAISER, G.: Diet Surveys to Revive Nutrition Programs. J. Home Ec., *38:* 517–519, 1946.
8. DOWNES, J., AND BARANOVSKY, A.: An Experiment in Nutrition Teaching by Public Health Nurses. Milbank Mem. Fund Quart., *23:* 227–253, 1945.
9. Paraguayan Rural Life—Survey of Food Problems, Food Supply Division of the Institute of Inter-American Affairs, Department of State, Washington, D. C., 1946.
10. BOSLEY, B.: A Practical Approach to Nutrition Education for Children. J. Am. Dietetic Assoc., *23:* 304–309, 1947.
11. LOCKWOOD, E.: Nutrition Education in the Elementary Schools. Doctorate Dissertation, Harvard School of Public Health, Boston, 1948.
12. WHITEHEAD, F. E.: Research in Nutrition Education. J. Am. Dietetic Assoc., *23:* 310–317,1947.
13. MCHENRY, E. W.: A Research Project in Health Education. J. Am. Dietetic Assoc., *24:* 9–11, 1948.
14. CHANEY, M. S., AND AHLBORN, M.: Nutrition. 3rd Ed. Houghton-Mifflin Company, 1943, pp. 357.
15. VAUGHN, M. E.: The Effectiveness of Visual Education in Teaching Nutrition to Mothers in a Well-Baby Conference. Master's thesis, Harvard School of Public Health, Boston, 1945.
16. RADKE, M., AND KLISURICH, D.: Experiments in Changing Food Habits. J. Am. Dietetic Assoc., *23:* 403–409, 1947.
17. RADKE, M., AND CASO, E. K.: Lecture and Discussion-Decision as Methods of Influencing Food Habits. J. Am. Dietetic Assoc., *24:* 23–31, 1948.
18. Homemakers Acceptance of Nutrition Information in an Urban Community. U. S. Dept. of Agriculture, Bureau of Agricultural Economics, Washington, D. C., 1948.
19. THAW, SOPHIE GORDON AND CASO, ELIZABETH K.: A Guide for Community Nutritionists. New York. The Nutrition Foundation, Inc., 1947.

SECTION VI

NUTRITION SURVEYS IN RELATION TO PROFESSIONAL TRAINING IN SCHOOLS OF MEDICINE AND PUBLIC HEALTH

The important role assigned to nutrition in public health (The Nutrition Foundation, 1943; Smith, 1944; Stare, 1947) has led to an increasing demand for properly trained workers. The recognition of this need has resulted in a statement of the educational qualifications of nutritionists in health agencies (Committee on Professional Education of the American Public Health Association, 1946). Similar recognition of the importance of nutrition in medicine has given rise to calls for the incorporation of increased instruction in the subject in the medical curriculum (Wilder, 1943; Editorial, 1947). The needs and training of professional personnel in nutrition have also been considered by the Section on Professional Education in Nutrition of the National Nutrition Conference for Defense (1941), by the Technical Committee on Nutrition and Food Management of the United Nations Interim Commission on Food and Agriculture (1945), and by Davidson (1947). Despite this wide recognition of need, no single formula has evolved for the training of nutrition personnel.

The nutrition survey has great value as a teaching device. It is useful from this standpoint at both the professional and non-professional levels. The purpose of this chapter is to discuss the usefulness of the survey method in the training of professional workers. It is not implied in this discussion that the survey affords complete experience for these workers, but rather specific examples will be cited to demonstrate that it may be a useful tool in training programs.

The over-all nutrition survey deals with clinical, laboratory, and dietary measures. It, therefore, brings into close association workers with backgrounds in clinical medicine, biochemistry, dietetics, home economics, and, often, social service, nursing, or health education. It is inevitable that there should be great exchange of ideas among these workers who have been brought together into a survey team. This association within the team for a period of months results in a broadened understanding of the problems encountered within the population and a sounder appreciation of the many aspects of these problems.

For the training of public health personnel, such as nutritionists, health educators, and nurses, an experience with a nutrition survey is of unusual benefit. It is of especial value if it occurs within the region in which the individual is to be responsible for corrective measures, for through such training the worker secures first-hand knowledge of the dietary habits, prejudices, and customs, as well as living conditions, of the population. In addition he learns of the local agencies within the area which are concerned with food production, preservation, and education, as well as the degree of community organization, the status of medical and dental care in the region, and many other useful attributes of the region. Such first-hand experience prepares workers at all levels for a more critical evaluation of the problems which are encountered. It enables them to appraise the reasons for the existence of certain dietary conditions and permits them to seek the proper assistance in instituting corrective programs. For example, if the milk supply of a town is insufficient to meet the demands of an adequate school-lunch program, the properly trained nutritionist will not immediately institute a campaign to induce the school child to drink unobtainable milk. Instead, his attention will be directed at the problem of increasing the available supplies from the milk-shed or toward obtaining an acceptable substitute, such as powdered milk, for the school-lunch program. The exact course which will attain the desired end will depend upon the many attributes of the community, and the intimate knowledge derived from the survey should prove useful in deciding upon the program to sponsor.

In addition to this over-all viewpoint which the nutrition survey affords, it provides students in schools of public health with an opportunity to observe examples of clinical deficiencies—an opportunity often denied students in those schools which are not intimately connected with schools of medicine. Simultaneously, it develops an understanding of the value and limitations of various criteria of deficiency.

Finally, repetitive studies upon a population group permit an objective measure of the effectiveness of nutrition teaching programs and, thereby, the adoption of the better methods. One example of this use of a dietary survey is that presented by Downes (1943) and Downes and Baranovsky (1945) who studied the alteration of dietary habits by Negro families following various degrees of emphasis upon nutrition in the teaching program of the public health nurse. Another example of a similar use of the nutrition survey is a study by Moser (1945) on the nutritional condition of children in two communities in South Carolina. In this investigation the effect was measured of provision of a school lunch upon the total dietary intake of the children. Among other findings, it appeared that in one community most families expected the newly provided "complete noon lunch" to substitute for the main meal of the day (previously taken in the evening). The importance in teaching of knowledge of such reactions of the community is obvious.

The summarized findings from surveys should serve as source material for planning group nutrition programs aimed at education of the non-professional nutrition workers, such as Red Cross groups, nutrition committees, county and home demonstration agents, teachers, and others. The education of these persons is often the direct or indirect responsibility of Schools of Public Health, the graduates of which may be called upon to organize training programs for non-professional workers. An example of the employment of data from nutrition surveys in such programs may be cited: In 1945, the Tennessee-Vanderbilt Nutrition Project summarized as follows the more tangible nutritional problems as revealed by the surveys made in the State.

> "1. Obesity in adults, especially among women. This is primarily due to excessive intake of calories.
> 2. Substandard weights in some groups of children up to 15 years of age. In part, a reflection of caloric undernutrition, especially related to lack of breakfast.
> 3. Poor quality school lunches carried from home or served in some schools. These are often deficient in quantity as well as quality.
> 4. Iron deficiency in children under 2 years of age who are fed on milk alone. Iron deficiency type of anemia in some groups of women, occurring especially at the menopause and shortly

after delivery. Education should be directed toward the importance of prevention by seeking proper medical care.

5. Low protein intake by some farm families, by some school children, and by some pregnant and lactating women.
6. Low intake of vitamin C, riboflavin, and calcium by a portion of the lactating mothers.
7. Poor dental status of school children. This is a reflection of many factors, nutritional and non-nutritional. Some of the former may be the excessive use of sugars, candies, cold drinks, etc. The failure to recognize the importance of adequate dental care for deciduous teeth is probably of great importance in this problem."

This summary served as a guide for points to be emphasized in the teaching program carried out by the nutrition consultants of the State Health Department and also served as material for program planning by the State Nutrition Committee. A copy of it was incorporated in the Agricultural Extension Service Program which was provided the various community clubs. The nutrition programs of these clubs were then built around the solutions to the problems which the nutrition surveys had revealed. Most recently this summary has been incorporated in a newly prepared manual of health education for Tennessee schools, a manual sponsored jointly by the Department of Education and the Tennessee Department of Public Health. The wider employment of data from local surveys in a manner similar to this should result in much sounder and more convincing teaching programs. Illustrative data taken from the local study and properly interpreted to community groups may serve as basic material for non-professional training in community nutrition. The professional nutrition worker with an understanding of surveys is much better qualified to undertake these tasks.

Excellent field experience for personnel-in-training is provided by the more direct and individualized instruction of lay groups which almost invariably occurs during a nutrition survey. In order to secure local support of the survey, the survey team arouses the community consciousness of nutrition by means of talks to local clubs, community groups, medical societies, schools, and other agencies. Upon completion of the survey, the team has a definite obligation to report its findings to the community through these same media and to interpret them in terms of practical remedial measures. Finally, to the individual subjects who have participated, a complete report of the various studies made must be given either directly or through the subject's physician. The resulting education of individuals may be very effective.

Nutrition surveys which are limited to special groups, in contrast to those among the general population, may serve as catalysts for the development of a sound nutrition interest within medical schools. As an example of this type of development the experience at the School of Medicine of Vanderbilt University may be cited. During the years 1939–1941, the Departments of Medicine and Biochemistry collaborated in a series of nutrition surveys (Youmans *et al.*, 1943, '44, '45) within the general population. These were carried out under the direction of Doctor John B. Youmans. In 1943, these studies became a joint undertaking of the Tennessee Department of Public Health and of Vanderbilt University and continued to operate as such until July 1, 1947. In 1945, largely as a result of this continuous interest in nutrition surveys, five departments of the Medical School (Department of Preventive Medicine and Public Health, Department of Obstetrics and Gynecology, Department of Pediatrics, Department of Medicine, and Department of Biochemistry) joined in an intensive nutrition survey of the women attending the prenatal clinic and of the infants born to these mothers. This study, known as the Vanderbilt Cooperative Study of Maternal and Infant Nutrition, has been under way for a period of 2 years and is expected to continue for an additional 3-year period. Members of each of the departments named are participating actively in the study. This participation has brought about within these groups an increasingly widespread consciousness of the role of nutrition in the preservation of health as well as in diseased states. It has served as a stimulus to all of the cooperating investigators to study and appraise the potential and latent zones of nutritional deficiency as well as the clinically manifest diseases. Further, as a result of the interest in this cooperative study, some of the personnel of the cooperating departments have now undertaken independent investigations of nutritional diseases encountered within their field of specialization. Finally, in considerable part as a result of these two types of nutrition surveys, the special project previously sponsored jointly by the Medical School and the State Health Department has now been established as a permanent Division of Nutrition in the Departments of Biochemistry and Medicine of this Medical School. Although not all such surveys will result in such permanent developments within cooperating schools, they cannot fail to stimulate an increased interest in nutrition among the associated personnel.

In addition to these broader aspects of personnel training, the nutrition survey is peculiarly well adapted to provide training in methodology. This technique offers an ideal opportunity for training in the statistical approach to a problem, a discipline in which too few nutrition investigators have been versed in the past. This training in statistics is best secured by enlisting the cooperation of a biostatistician at the stage of preliminary planning of a survey and then working throughout the investigation and the processing of data in collaboration with the statistician (Muench, 1945, '47). As examples of studies which have been carried out in this manner may be cited the series on California aircraft workers (Wiehl, '42; Borsook, '45; Borsook and co-workers, '46; Borsook, Alpert and Keighley, '43; Borsook and Wiehl, '46) and the Vanderbilt Cooperative Study of Maternal and Infant Nutrition (to be published).

The ideal nutrition survey affords an unexcelled opportunity to the biochemist for an experience in critical scrutiny and standardization of laboratory methods. The literature of biochemistry and nutrition abounds with methods (some of them are widely employed) concerning which no quantitative statement regarding errors and variability have been presented. Most nutrition surveys have not improved this situation; a few, however, are noteworthy in their contributions in this direction. One of the best examples of the detailed study of the sources and magnitude of errors in a chemical procedure, the variability of the procedure, and the standardization of it, is given by the Committee on Hemoglobin Surveys of the Medical Research Council of Great Britain (1945). An experience with such an analysis would be an invaluable part of the training of a biochemist or physiologist. Somewhat similar analyses of the sources of error in another hemoglobin technique (Wiehl, 1946), as well as in a method for ascorbic acid (Wiehl and Kantorovitz, 1942; Beebe, 1942), have been provided. Development and extension of these approaches associated with the nutrition survey should provide a reservoir of personnel who are much better equipped to design and execute scientific investigations and to plan and evaluate health procedures (Muench, 1947).

The use of the many laboratory methods for the estimation of nutritional levels necessitates the training of chemical technicians in these procedures. The demand for such trained personnel has exceeded the supply and many of these technicians are now permanent members of the laboratory staff of hospitals, State Health Departments, and the like. Perhaps more important, however, than the training of technical personnel is the incentive which the nutrition survey has provided for the biochemist to develop methods which may be applicable in mass studies and the opportunity to test these methods in practice. Among the more remarkable of these techniques are the several microprocedures which have been described by Lowry, Bessey, and their co-workers (Lowry and Bessey, 1944, '46; Bessey and Lowry, '45; Lowry, Lopez, and Bessey, '45; Lowry and Hunter, '45; Bessey *et al.*, '46). Again, as technical personnel have been trained in these specialized procedures, the demand for them has risen because these techniques are being applied in numerous problems other than those concerned with nutrition surveys.

From the standpoint of allotting nutrition its deserved place in the practice of medical specialties, perhaps one of the most significant contributions of nutrition surveys is that which results from the temporary association of medical personnel with surveys. These physicians often separate from the nutrition study and return to their medical specialty. It is inevitable that the carry-over of nutritional thinking by these persons will be large and that it will influence their own medical practice as well as that of their colleagues. The nature of the field makes such developments of extraordinary importance in the dissemination of sound nutrition practice.

BIBLIOGRAPHY

1. Beebe, G. W.: Medical Evaluation of Nutritional Status. XIII. The Experimental Error of Determinations of Ascorbic Acid in Plasma by Micromethod of Mindlin and Butler. Milbank Mem. Fund Quart., *20:* 389–415, 1942.
2. Bessey, O. A. and Lowry, O. H.: Biochemical Methods in Nutritional Surveys. Am. J. Pub. Health, *35:* 941–946, 1945.
3. Bessey, O. A., Lowry, O. H., and Brock, M. J.: A Method for the Rapid Determination of Alkaline Phosphatase with Five Cubic Millimeters of Serum. J. Biol. Chem., *164:* 321–329, 1946.
4. Borsook, H., Alpert, E., and Keighley, G. L.: Nutritional Status of Aircraft Workers in Southern California. II. Milbank Mem. Fund Quart., *21:* 115–157, 1943.
5. Borsook, H.: Nutritional Status of Aircraft Workers in Southern California. III. Milbank Mem. Fund Quart., *23:* 113–160, 1945.
6. Borsook, H. and co-workers: Nutritional Status of Aircraft Workers in Southern California. IV. Milbank Mem. Fund Quart., *24:* 99–185, 1946.
7. Borsook, H. and Wiehl, D. G.: Nutritional Status of Aircraft Workers in Southern California. V. Milbank Mem. Fund Quart., *24:* 251–299, 1946.
8. Committee on Haemoglobin Surveys, Medical Research Council: Haemoglobin Levels in Great Britain in 1943 (with Observations upon Serum Protein Levels). London. His Majesty's Stationery Office, 1945.
9. Committee on Professional Education of the American Public Health Association: Proposed

Report on the Educational Qualifications of Nutritionists in Health Agencies. Am. J. Pub. Health, *36:* 45–50, 1946.

10. Davidson, L. S. P.: The Teaching of Nutrition to Medical Students. Brit. J. Nutrition, *1:* 102–107, 1947.
11. Downes, J.: Recent Changes in Income and Food Expenditures Among Tuberculosis Families in Harlem. Milbank Mem. Fund Quart., *21:* 158, 1943.
12. Downes, J.: A Study of Food Habits of Tuberculosis Families in a Harlem Area of New York City. Milbank Mem. Fund Quart., *21:* 164, 1943.
13. Downes, J. and Baranovsky, A.: An Experiment in Nutrition Teaching by Public Health Nurses. Milbank Mem. Fund Quart., *23:* 227–253, 1945.
14. Editorial: The Teaching of Nutrition. I, II, III, and IV. J. A. M. A., *133:* 1282; *134:* 23, 146, 292, 1947.
15. Lowry, O. H. and Bessey, O. A.: A Method for the Determination of Five-tenths to Two Millimicrograms of Riboflavin. J. Biol. Chem., *155:* 71–77, 1944.
16. Lowry, O. H., Lopez, J. A., and Bessey, O. A.: The Determination of Ascorbic Acid in Small Amounts of Blood Serum. J. Biol. Chem., *160:* 609–615, 1945.
17. Lowry, O. H. and Hunter, T. H.: The Determination of Serum Protein Concentration with a Gradient Tube. J. Biol. Chem., *159:* 465–474, 1945.
18. Lowry, O. H. and Bessey, O. A.: The Adaptation of the Beckman Spectrophotometer to Measurements on Minute Quantities of Biological Materials. J. Biol. Chem., *163:* 633–639, 1946.
19. Moser, A. M.: Nutritional Condition of Children in Relation to School Lunches in Two South Carolina Rural Communities. Bull. 359, South Carolina Agricultural Experiment Station, Clemson, South Carolina. 1945, p. 54.
20. Muench, H.: Experiments and the Statistician. Nutrition Rev., *3:* 321–322, 1945.
21. ——: Statistics in the Planning and Evaluation of Health Procedures. Am. J. Pub. Health, *37:* 1273–1276, 1947.
22. Section on Professional Education in Nutrition, National Nutrition Conference for Defense. Proceedings National Nutrition Conference for Defense: p. 146. Washington, D. C. May 1941.
23. Smith, H. H.: Nutrition and Public Health. Nutrition Rev., *2:* 257–261, 1944.
24. Stare, F. J.: Medical and Public Health Education in Nutrition. Nutrition Rev., *5:* 1–4, 1947.
25. Technical Committee on Nutrition and Food Management, United Nations Interim Commission on Food and Agriculture: Five Technical Reports on Food and Agriculture, p. 86. Washington, D. C. 1945.
26. The Nutrition Foundation: Proceedings Research Conference on the Relation of Nutrition to Public Health. New York. October 11, 1943.
27. Vanderbilt Cooperative Study of Maternal and Infant Nutrition. To be published.
28. Wiehl, D. G.: Diets of a Group of Aircraft Workers in Southern California. Milbank Mem. Fund Quart., *20:* 329–365, 1942.
29. ——: Accuracy of Hemoglobin Determinations in Fingertip Blood. Milbank Mem. Fund Quart., *24:* 5–28, 1946.
30. —— and Kantorovitz, M.: Medical Evaluation of Nutritional Status. XI. An Analysis of Sources of Errors in Photelometric Macromethod of Determining Ascorbic Acid in Plasma. Milbank Mem. Fund Quart., *20:* 178–206, 1942.
31. Wilder, R. M.: The Teaching of Nutrition in Schools of Medicine. J. Assoc. American Medical Colleges, *18:* 145–157, 1943.
32. Youmans, J. B. and co-workers: Surveys of the Nutrition of Populations, 1, 2, 3, and 4. Am. J. Pub. Health, *32:* 1371; *33:* 58, 955–964; *34:* 368–378, 1943–1944.
33. —— and ——: Surveys of the Nutrition of Populations. Am. J. Hyg., *42:* 254–261, 1945.

SECTION VII

THE ROLE OF HEALTH DEPARTMENTS IN NUTRITION SURVEYS AND APPRAISAL

PAGE
Introduction 132
Development of Public Health Nutrition Appraisal Services 133
    Sphere of Activity of Public Health Agencies 133
    The Epidemiological Approach to Nutrition Problems 133
        The importance of epidemiological information 133
        Some examples of epidemiological studies 134
    Some Problems in the Nutritional Appraisal of Groups 135
        Malnutrition, a group of diseases 135
        The characteristics of procedures suitable for public health use 135
        Some problems in correlation of findings 136
    Dissemination of Information and Education of Groups 136
        Motivation of group surveyed 136
        Use of results in long range programs 136
Health Agencies Serving Different Units of Population 137
    International Agencies 137
        World Health Organization 137
        Food and Agriculture Organization 137
        Pan-American Sanitary Bureau 138
    National Health Agencies 138
        Examples of national public health nutrition services 138
        Some suggestions for expanding national services 140
    State, Territorial, and Provincial Health Agencies 141
    Local Health Agencies 141
Bibliography 142

INTRODUCTION

The purpose of this section is to suggest a public health approach to nutrition problems and to point out types of nutritional survey and appraisal work that are most suitable for health departments and related health agencies. Detailed directions for diagnostic procedures are discussed in other sections.

The terms "survey" and "appraisal" are used in a broad sense to include any fact-finding on a public health scale which aids in defining the nutrition problems of population groups or helps to clarify the epidemiology of health conditions related to nutrition.

Obviously, the health department can make limited surveys independently or cooperate with other groups. Its functions and activities will vary accordingly. There are many aspects of nutrition that are primarily the responsibility of other groups, for example, agricultural agencies (1) (2). No one professional group is equipped with the training, experience, or facilities to deal with all phases of nutrition. Whether on an international, national, state, or local basis, the best results come from well-planned cooperative efforts made to answer specific questions. A free interchange of information among the different groups is of advantage.

Nutrition surveys vary widely in character, scope, and degree of complexity. Some are long-range or continuing, whereas others necessarily cover only brief periods of time; some are designed to answer only a few simple questions, while others are quite extensive. Health agencies planning to cooperate in nutrition surveys, or anticipating limited surveys of their own, might consider the following simple questions:

1. Why is the survey being planned?
2. What specific information is wanted?
3. What is the simplest possible way to obtain it?
4. Are personnel, time, and funds adequate for carrying out the plans?
5. What will be done with the information gained?

DEVELOPMENT OF PUBLIC HEALTH NUTRITION APPRAISAL SERVICES

A. Sphere of Activity of Public Health Agencies.—Since different groups are working in this field, many health officials have wondered just what the responsibilities of the health department are (3) (4). This is an important question. In brief, the answer seems to lie in the pattern that has been followed in dealing with other public health problems. If this is true, the health department can contribute most to the *epidemiological* aspects of a national, state, or community nutrition program and can participate in other respects, insofar as practicable (5). The responsibilities might be divided into three phases, as follows:

1. Epidemiological fact-finding designed to locate, analyze, and define nutrition problems.
2. Dissemination of epidemiological information based on the results of investigations.
3. Assistance, directly and through other groups, in corrective and preventive measures.

B. The Epidemiological Approach to Nutrition Problems.—1. The importance of epidemiological information in the field of nutrition: In spite of the mass of nutrition data now accumulated, there is a paucity of information on the epidemiology of many nutrition problems in different areas. Epidemiology applies in the field of nutrition as well as in the field of communicable diseases. It involves the answers to such questions as Who?, What?, Where?, When?, Why?, and How? Some such questions will have to be answered by groups other than public health, and this is one of the reasons for well-planned cooperative studies. It is not enough to know that a given disease is caused by a certain deficiency, but for practical purposes it is necessary to know what habits or conditions bring about the deficiency. Here one may find examples of a merging of the fields of medicine, public health, agronomy, sociology, economics, education, etc.

More health workers, national, state, and local, are beginning to study nutrition as to cause and effect, that is, from the standpoint of etiology of disabilities and the effects of different degrees of nutritional adequacy on physiological efficiency, health level, and longevity. There is need for more study on the possible advantages of better-than-usual nutrition. So-called "optimal nutrition" has not yet been defined clearly, and therefore its potentialities cannot be estimated until much more work is done. Investigative work of this character will point the way toward more satisfactory criteria for nutritional appraisal.

Such problems present a whole new field of opportunity for public health agencies. What other group has the entree, prestige, and medical and scientific background and experience to make comprehensive studies designed to answer questions of this kind?

2. Some Examples of Epidemiological Nutrition Studies: A classical example of an epidemiological approach is the well-known work of Doctor Joseph Goldberger on pellagra (6) (7) (8) (9).

Goldberger studied pellagra in several southern states and used a variety of approaches, all of which tended to give the same answer. He made simple, direct observations, including careful study of both anatomical lesions and functional disorders.

By the application of epidemiological methods, Goldberger found that this disease was not only related to the diet but was due to shortages of unknown nutrients which were present in certain foods and lacking in others. He set up practical though empirical means of combatting the disease. It was several years after Goldberger's death that nicotinic acid, a simple chemical compound, was found to be curative for pellagra (10) (11) (12).

Another illustration of the epidemiological approach to a medical problem on a public health scale is the work of Marine and Kimball (13) and others on simple goiter. Outlined below are some of the more important findings. Simple goiter was found to be:

a. common in certain areas and not in others
b. more prevalent in females than in males
c. more severe in females than in males
d. more prevalent in areas with water supplies low in iodine
e. roughly inversely proportional in prevalence and severity to the iodine content of the water
f. artificially producible in animals by diets low in iodides
g. due to a low intake of iodine
h. prevented by addition of small amounts of iodides to the diet (therapeutic tests)
i. curable in its early stages by iodides (therapeutic tests)

These studies were comprehensive, statistically sound, and left no reasonable doubts as to the cause and prevention of simple goiter.

Following these findings it was not long before several State health departments, including those of Washington (13), Utah (14), and Oregon (15), began surveys to determine the prevalence and severity of this type of goiter in segments of their populations. In Utah, 110,000 individuals were examined for simple goiter during the years 1924–25. One county showed an incidence of 83.5 per cent. The lowest incidence found in any county was 26.3 per cent. Similar surveys were made in several other states including Colorado, Ohio, Minnesota, and Michigan (16).

The relationship of fluorine to dental caries has offered another area for epidemiological investigation of a problem apparently related to nutrition. Over a period of nearly 20 years Dean and his associates have studied the relationship of fluorine intake (content of drinking waters) to dental caries (17) (18). They have approached this problem in various ways.

This group found that children who drink fluorine-containing waters during their first 8 or 10 years of life have fewer cavities in their permanent teeth than do children who drink fluorine-free waters during this period. About 2 or more ppm. of fluorine in water causes mottling of the permanent teeth, while about 1 ppm. is sufficient to exert a protective influence against caries without producing mottling. These observations have been made on a large scale in many sections of the United States.

A comprehensive study is under way in Grand Rapids, Michigan, of the prophylactic effect on dental caries of *adding* 1 ppm. of fluorine to drinking water. The study is to continue over a period of years. A similar study is being made by the New York State Department of Health in Newburgh, New York. Other investigations are under way in: Brantford, Ontario; Midland, Michigan; and Sheboygan, Wisconsin.

These investigations on pellagra, simple goiter, and dental caries illustrate how public health and other medical groups can study epidemiologically a given condition and seek means for its prevention.

C. Some Problems in the Nutritional Appraisal of Groups.—1. Malnutrition, a group of diseases: The term "malnutrition" as sometimes used appears to designate a single disease. Such usage is misleading since the term does not indicate a single disease entity any more than does the term "infectious disease" (19) (20) (21). It follows, then, that a diagnosis of "malnutrition' is as unspecific as is a diagnosis of "infectious disease." Such diagnoses designate only the general *type* of etiology. One term embraces a group of diseases and disabilities caused by improper intake or assimilation of various food substances; the other term embraces a large group of diseases caused by pathogenic organisms. The signs, symptoms, and pathology of different nutritional diseases may be as diverse as those of various infectious diseases.

Conditions of nutritional origin occur in various combinations and in different degrees of severity, acuteness, and chronicity. Also, they are often complicated by other pathology. Obviously, then, no single test can diagnose malnutrition.

2. Characteristics of Procedures suitable for public health use: Most medical diagnostic methods have been developed for use in private or hospital practice, and many of them are too slow, cumbersome, or expensive for use on a public health scale. This is true of methods used in diagnosing different nutritional conditions (22). Some methods are applicable to group work only in very special circumstances and are not suitable for general field use. Some are too fine for use as screening or diagnostic procedures for groups. Some are subject to wide ranges of interpretation. Apparently such difficulties have discouraged many health officials from attempting nutrition appraisal work.

Public health workers have overcome such obstacles in other fields. For example, in communicable disease work there has been some division of responsibility. This has made it possible for different groups to focus attention on different problems.

In the field of tuberculosis, health workers have developed simple, rapid, and inexpensive diagnostic methods that are suitable for use by health agencies. This is also true of venereal diseases and certain other conditions. Nutrition appraisal techniques for public health use also should be simple, rapid, reasonably accurate, inexpensive, and productive of significant findings.

3. Some problems in correlation of findings: A survey is comparable to a group diagnosis. Health agencies serving different units of population are already accustomed to working with groups of people. No matter how homogeneous a group may appear to be, the findings on individuals comprising it may vary widely.

Before a survey is begun, definite plans for analyzing the results should be formulated (23). A person trained in biological statistical methods should be available to assist in the planning.

When different types of method are used in a single survey, sometimes results appear to be inconsistent. One often encounters the same difficulties in making a diagnosis on a single individual; for example, the data from certain laboratory tests may show little correlation with physical findings, diet records, etc. This is not surprising, since such procedures are not perfect, nearly all are subject to interpretation, and sometimes correlations are expected when they do not exist. Experienced workers in this field have encountered this problem many times.

Closer correlations among different approaches may be apparent when underlying physiology, pathology, and conditioning factors, physical signs and symptoms, laboratory results, diet records, etc., gradually come to be better understood in relation to each other. In the meantime, precautions should be taken in the final interpretation of results.

D. Dissemination of Information and Education of Groups.—1. Motivation of group surveyed: When a nutrition survey is planned, two important educational opportunities should be considered: (a) use of the motivation which can be generated by the survey to improve any unfavorable conditions found, and (b) use of findings for educating the larger group of which the survey group is a sample. These are not by-products, but rather the ultimate purpose of the survey. In making a survey one accepts such responsibility, at least by implication, toward the people studied.

This is true even when surveys are made primarily for scientific purposes. Thus, unexpected antagonisms can often be avoided. Also, more accurate information is likely to result from interested cooperation than from reluctant or incomplete cooperation.

If a long-range study is begun or therapeutic testing is planned, it may be desirable to delay educational efforts until certain "experimental" phases of the study are completed. The reasons are obvious. For example, diet records are taken very casually before anything is said about what the diet *should* contain. Such records, when compiled, should give an approximation of eating habits before any effort is made to change these habits. Of course, records may be taken again following educational efforts directed at improvement.

Educational follow-up should be planned as an integral part of the survey (24). If educational opportunities are not to be utilized locally in connection with a survey, this should be understood in the beginning by the individuals to be studied.

2. Use of results in long-range programs: Group nutrition problems and their ultimate causes should be studied as to both relative importance and probable degree of remediability. When this is done, emphasis can be properly placed in both immediate and long-range educational programs.

Health departments seek first-hand information regarding the prevailing nutrition problems of the group as a basis for educational activities directed at preventive measures for unfavorable conditions found. These may be taken immediately (short-range), or may be directed at the ultimate solution of the underlying factors (long-range). Usually, a combination of these is desirable.

Soon after Marine and Kimball's (13) work on endemic goiter, many other studies and surveys were made in different sections of the country. The problem was found to be most acute in the Great Lakes region and the Northwest, although widely-distributed smaller endemic areas were found. Of all the areas with a moderate to severe endemic goiter problem, the state of Michigan was the only large area to initiate a sustained, long-range, educational campaign for the application of preventive measures, i.e., the use of iodized salt.

Rarely would the health department adopt direct corrective measures (such as feeding) except in emergencies or for demonstration purposes and then only on a temporary basis (25) (26) (27), for example, yeast furnished to a pellagrous individual. Even this must be accompanied by efforts to improve food habits and conditions underlying poor food habits.

Much wider educational coverage can result when health agencies channel new information through other organized groups, e.g., the schools (28), which come into direct contact with more people for longer periods of time than does the health department.

HEALTH AGENCIES SERVING DIFFERENT UNITS OF POPULATION

A. International Agencies.—1. World Health Organization: Prominent among the health objectives of the League of Nations (29) was the improvement of conditions related to food and nutrition. Food was recognized as a common denominator among the nations of the world.

More recently the United Nations, through the World Health Organization (30), is making the second world-wide attempt to deal with health problems on an international scale. World conditions (31) (32) have forced the nutrition problem to the forefront among those destined to influence the course of world events.

2. Food and Agriculture Organization: Aside from emergencies such as war, famine, etc., there is an increasing tendency for food and nutrition authorities to assume a world-wide view of food and nutrition economics. This is in addition to the obvious health implications (33) (34). The Food and Agriculture Organization is an outgrowth of this trend and represents a concerted effort being made by over fifty nations to deal more effectively with food problems which have long been international in character. World War II and its aftermath have emphasized the necessity for voluntary cooperative measures.

It is generally known that national food habits in some countries are detrimental to health (35) (36) and must be improved before certain other public health efforts can become effective. There are indications that public health agencies of different countries will soon be able to furnish more specific information about pressing food needs by providing reliable data based on nutrition appraisals of groups. Admittedly this is a new responsibility for national and international public health organizations.

3. Pan-American Sanitary Bureau: At present 21 nations of the Western hemisphere belong to the Pan-American Sanitary Bureau. A number of these countries in South and Central America (37) are organizing nutrition survey, study, and appraisal units. Representatives from some of these countries are receiving special training in the United States and in Mexico to participate in this program. It is planned that each unit will be directed by a person trained in medicine and nutrition, and will also include one or more nutritionists, a biochemist, and an agronomist. Such units will serve as nuclei for further development if there is continued and increased support by the several countries.

It is feasible for several smaller countries to pool their resources for voluntary cooperative nutrition work under the guidance of international organizations. For example, authorities in Guatemala, Honduras, El Salvador, Nicaragua, Costa Rica, and Panama are planning joint sponsorship of a central nutrition laboratory to be located in Guatemala City. It will serve also as a training and information center for nutrition workers employed by the individual countries. Such cooperative effort would hardly be possible without some form of international sponsorship.

B. National Health Agencies.—The administration and duties of national health agencies interested in nutrition vary from country to country and depend upon a variety of conditions. Some of the objectives and functions of such agencies (38) are discussed below.

A recent poll (39) of 541 public health workers in the United States and Canada indicates an overwhelming opinion that a national health agency should carry out such functions as:

(a) Close cooperation with other national agencies seeking nutrition information.
(b) Collection, analysis, and distribution of nutrition information pertinent to the State and local health departments and the general public.
(c) Consultation to agencies in smaller units of government.
(d) From all available information, furnish facts as a basis for national legislation which will contribute to the improvement of the nutritional status of the public.

Cooperating with smaller units of government (40), national health agencies can assist in and encourage surveys and appraisals on regional bases where problems of a regional nature exist (41). Within recent years agricultural and college groups have cooperated in making such regional studies (42) (43).

There is evidence of increasing interest in nutrition problems by national health agencies in many countries. A few examples are given below:

1. Examples of national public health nutrition services: Canada: Among the better-known national public health nutrition units is the Nutrition Division of the Department of Health and Welfare of Canada. This unit consists of a small staff headed by an individual trained in medicine, nutrition, and public health. This staff serves as a consultation unit for public health workers in the different Provinces of Canada.

Recently the unit made hemoglobin determinations on nearly 1500 school children in 5 areas (44). Nine per cent of these children were found to have hemoglobin levels below 11.9 gm. per 100 cc., which, for purposes of the study, was taken as the dividing line between satisfactory and unsatisfactory hemoglobin levels. Possible sources of error in making such determinations were discussed and emphasized. The causes of the small percentage of anemia found were not reported.

In 1947 a report was made of a nutrition study of 3200 children in British Columbia and Saskatchewan (45). This study included diet records, laboratory tests, and physical inspections, and was the first such nutrition survey made in Canada. The authors state that, "The surveys are designed to assist local and provincial personnel in ascertaining the type and extent of the nutrition problem, and the means of solving it."

Newfoundland: In 1944 the Commissioner for Public Health and Welfare of the government of Newfoundland organized and sponsored a medical nutrition survey. The study was carried out by some of the leading nutrition authorities of the United States and Canada. A 32-page report, with colored plates and an extensive bibliography, was published in the *Canadian Medical Journal* in 1945 (46). The survey included: an investigation of economic and living conditions, a compilation of data regarding general health, food consumption studies, clinical examinations, biochemical determinations, and an assessment of the available food supply. The study was made on a sample of 868 people in 6 typical areas.

This survey was made in August 1944 and is an example of a short-term intensive study designed to point up specific deficiencies as well as other problems related to nutrition. Reprints of the report have been widely circulated.

This survey was repeated by the same group of physicians in 1948, in order to determine the effect of measures taken to remedy the deficiencies observed in the 1944 survey. Many of those examined in the first survey were re-examined in 1948. The results illustrate how the effectiveness of public health nutrition reforms can be measured and made to provide a factual basis for further development of public health programs and practices.

Egypt: Medical and public health agencies in Egypt have begun nutrition appraisal studies using mobile nutrition survey units (47). These are under the direction of a person trained in medicine, public health, and nutrition.

Philippines: A study to determine the effects of rice enrichment has been undertaken on Bataan through the U. S. Public Health Service and the Department of Health of the Republic of the Philippines.

A nutrition study based chiefly upon microchemical methods was carried out in Bataan, Philippine Islands, during the summer of 1948. Earlier studies had been based chiefly upon physical examinations and diet records. Blood thiamine levels were observed in a population where beri-beri was endemic (70). These initial thiamine levels will serve for making comparisons after a period of feeding enriched rice. The survey was conducted under the auspices of the Williams-Waterman Fund of the Research Corporation in coöperation with the Nutrition Foundation, the U. S. Public Health Service of the Philippines, and Columbia University. The 200 subjects were classified clinically, in relation to beri-beri, as frank, suspected, doubtful, and nonsymptomatic. Significant differences were found in blood thiamine levels of frank and suspected cases compared with doubtful and non-symptomatic cases. The general averages paralleled the symptomology rating. Determination of hemoglobin and serum protein in the field laboratory revealed low hemoglobin levels in general and a high incidence of severe anemia, with serum protein in a relatively normal range. Analyses of serum for ascorbic acid, vitamin A, and carotene in the laboratories of Columbia University indicated a high incidence of deficiencies in ascorbic acid and carotene. The observed low intake of green and yellow vegetables and fruits afforded an explanation of these two deficiencies.

United States: In 1945 a nutrition section was established in the States Relations Division of the United States Public Health Service (38). Survey teams, which include physicians, nurses, nutritionists, and biochemists, have done nutrition surveys of communities in several areas. This national public health nutrition service will help develop the epidemiological approach to nutrition problems in the United States (48).

2. Some suggestions for expanding national services: Some functions that can probably best be performed by national groups are discussed below.

Most public health workers who have attempted to do nutrition appraisal work have recognized the need for more study directed at standardization of nutrition measurements of all types. So many different criteria are being used that two different groups making surveys in the same area could arrive at quite different conclusions.

The need for evaluation and standardization of laboratory apparatus is urgent. This is particularly true of some of the newer instruments. Such instruments should be appraised under field conditions as to comparative accuracy, reliability, and durability per se and also in relation to cost.

Even some simple items as purchased on the open market may be grossly inaccurate. For example, recently the writers found 20 cu. mm. blood pipettes to deliver as much as 40 per cent too much blood. Numerous such pipettes are found to vary from 5 to 15 per cent from the measurement indicated. It is not always feasible to use exclusively apparatus calibrated by a Bureau of Standards.

A variety of photoelectric colorimeters may give quite divergent results, but some are undoubtedly more dependable than others. Numerous hemoglobinometers on the market today give results which vary considerably. These are but a few examples of equipment of unknown reliability that the public health worker may encounter.

Also, techniques are far from uniform and, therefore, should be critically tested and evaluated. What are the most reliable chemical and hematological methods used in this field? What are the most satisfactory methods of quantitating physical findings? What are the most practical techniques for therapeutic testing in various situations? These are some of the types of questions discussed in Sections I, III, and IV and which deserve further study.

A field to be explored carefully is that of possible relationships between nutrition and various other health problems (49) (50) (51) (52) (53) (54). For example, Trudeau found in 1884 that adequate feeding showed a positive correlation to the healing of tuberculosis (55). Since then, however, little has been done to study and analyze this relationship (56). Knowledge regarding possible relationships of specific nutrients to either susceptibility or treatment of various diseases is still far from complete.

Public health agencies are interested in the relationships of etiologies as well as in the prevalence and severity of specific health problems. This is important in the field of nutrition. National health and related agencies have an opportunity to make epidemiological studies of such relationships.

C. State, Territorial, and Provincial Health Agencies.—A poll of 541 public health workers (39) in the United States and Canada (conducted by the authors) indicates the consensus that State and Provincial Health Departments should set up nutrition units under medical direction to study, appraise, and define nutrition problems within their respective areas (57) (58) (59). The majority feel that the educational programs being carried out by most State departments are good but should be expanded.

Since it is becoming more apparent that nutrition problems are intimately associated with other medical and public health problems, it is increasingly clear that State health agencies must do more to define their own nutrition problems by reorienting their nutrition programs to include more fact-finding, survey, and appraisal (5) (60). One of the first steps would be to collect and study all existing data bearing on the subject within the state.

State agencies naturally assume a position between national and local groups. In nutrition survey work the State group will have some of the characteristics of both the national and the local units.

Few local health departments, except under special circumstances, will be equipped in the near future to carry on extensive nutrition work of an investigative character. The major part of such work will have to be done by State health departments, working in cooperation with local departments. Special personnel will have to be furnished largely by the State.

Undoubtedly nutrition personnel requirements will vary from state to state (61) but facilities should be available for clinical appraisal, biochemistry, hematology, diet studies, and parasitology (in areas where parasitic diseases are prevalent).

Few State health departments have facilities outside of the central laboratories for doing nutrition laboratory work. Mobile laboratories (33) and portable equipment (46) have proved useful in nutrition field-work.

State health departments anticipating nutrition survey programs can begin modestly. Small survey units under medical direction can begin to do nutrition surveys of a limited character (62) (63) (64). These can be directed at single problems (25) (26). Health departments need information on the role that both malnutrition and good nutrition are playing within their areas.

D. Local Health Agencies.—Recently many local health departments have become interested in community nutrition as a public health problem (65) (66). Such departments find it desirable to gather and compile any information which is already available on nutrition in their own communities. The value of such information is increased when it is brought together and studied by interested groups within the community (67). This was amply demonstrated by the work of community nutrition committees during World War II. Some county and city health departments (66) have employed full-time or part-time nutritionists.

Most local health departments are not in a position to carry out extensive nutrition surveys independently. Limited surveys, however, especially in cooperation with other local groups, are feasible (68). Such studies not only furnish certain facts that are needed but also provide motivating influences toward improving food habits and other conditions which contribute to poor nutrition in the community (69).

If the local health department is planning nutrition survey work it might choose a given problem and, with the simplest procedures possible, study one phase of it at a time. For example, those doing school and pre-school examinations might give extra attention to signs and symptoms which suggest nutritional difficulties; diet records might be kept by representative groups of school children or other organized groups; hemoglobin tests might be done on appropriate population samples and, if unexplained low levels are found, a plan of therapeutic testing with specific substances might be carried out. These are but a few examples of the types of simple beginnings that can be made. Conditioning factors should be considered and adequate control groups should be included.

Probably many local health departments have neglected nutrition appraisal work because of the feeling that they could not do a complete job. Actually, it is frequently preferable to begin modestly and expand gradually.

BIBLIOGRAPHY

1. MAYNARD, L. A.: Food Production for Better Health and Longer Life. *In* Nutrition and Public Health in the Postwar Period. Detroit, Michigan. Children's Fund of Michigan, 1944.
2. Food and Nutrition Investigations of the Agricultural Experiment Stations. U. S. Dept. of Agriculture, Office of Experiment Stations. Washington, D. C., 1945.
3. JAMESON, W.: The Place of Nutrition in a Public Health Program. Am. J. Pub. Health, *37:* 1371–1375, 1947.
4. SEBRELL, W. H. AND WILKINS, W.: The Role of the Health Department in the National Nutrition Program. U. S. Pub. Health Rep., *58:* 803–813, 1943.
5. WILKINS, W.: New Types of Activity for Nutrition Services in Public Health. Milbank Mem. Fund Quart., *25:* 247–255, 1947.
6. GOLDBERGER, J.: The Etiology of Pellagra. U. S. Pub. Health Rep., *29:* 1683–1686, 1914.
7. GOLDBERGER, J., WARING, C. H., AND WILLETS, D. G.: The Prevention of Pellagra. A Test of Diet Among Institutional Inmates. U. S. Pub. Health Rep., *30:* 3117–3131, 1915.
8. GOLDBERGER, J. AND WHEELER, G. A.: Experimental Pellagra in the Human Subject Brought About by a Restricted Diet. U. S. Pub. Health Rep., *30:* 3336–3339, 1915.
9. PARSONS, R. P.: Trail to Light, A Biography of Doctor Joseph Goldberger. New York. Bobbs-Merrill Company, 1943.
10. ELVEHJEM, C. A., MADDEN, R. J., STRONG, F. M., AND WOOLEY, D. W.: Relation of Nicotinic Acid and Nicotinic Acid Amide to Canine Black Tongue. J. Am. Chem. Soc., *59:* 1767–1768, 1937.
11. FOUTS, P. J., HELMER, O. M., LEPKOVSKY, S., AND JUKES, T. H.: Treatment of Human Pellagra with Nicotinic Acid. Proc. Soc. Exp. Biol. Med., *37:* 405–407, 1937.
12. SPIES, T. D., COOPER, C., AND BLANKENHORN, M. A.: The Use of Nicotinic Acid in the Treatment of Pellagra. J. A. M. A., *110:* 622–627, 1938.
13. KIMBALL, O. P.: Endemic Goiter and Public Health. Am. J. Pub. Health, *18:* 587–601, 1928.
14. Goiter Study, Utah State Board of Health. Salt Lake City, Utah, 1925.
15. OLESEN, R.: Endemic Goiter in Oregon. U. S. Pub. Health Rep., *42:* 2831–2849, 1927.
16. OLIN, R. M.: Iodin Deficiency and Prevalence of Simple Goiter in Michigan. J. A. M. A., *72:* 1328–1332, 1924.
17. DEAN, H. T.: Dental Caries and Fluorine. A. A. A. S., Washington, D. C., 1946. p. 5.
18. ——: Post-War Implications of Fluorine and Dental Health. Epidemiological Apects. Am. J. Pub. Health, *34:* 133–143, 1944.

19. Wilkins, W.: Nutrition From the Doctor's Point of View. Virginia Medical Monthly, *71:* 374–379, 1944.
20. Wilkins, W.: Health Problems in Nutrition. Mississippi Doctor, *22:* 279–284, 1945.
21. American Medical Association, Council on Foods and Nutrition: Vitamin Deficiencies: Stigmas, Symptoms and Therapy. J. A. M. A., *131:* 666–667, 1946.
22. Nutrition Survey of Population Groups. Report of a Conference on Methods and Procedures. U. S. Pub. Health Rep., *57:* 189–194, 1942.
23. Muench, H.: Planning Research From the Viewpoint of Later Interpretation of Data. Proceedings, Research Conference on the Relation of Nutrition to Public Health. New York. The Nutrition Foundation, 1943.
24. Wilkins, W., Blakely, R., and Brunson, J.: Hemoglobin Levels of Parker High School Students. J. South Carolina Med. Assoc., *43:* 31–33, 1947.
25. Milam, D. F. and Wilkins, W.: Plasma Vitamin C Levels in a Group of Children Before and After Dietetic Adjustment. Am. J. Trop. Med., *21:* 487–491, 1941.
26. —— and ——: Vitamin C in Normal Nutrition. South. Med. & Surgery, *104:* 191, 1942.
27. Wilkins, W. and Boyd, F.: A Nutrition Demonstration as a Tool for Teacher Training. J. School Health, *12:* 35–42, 1942.
28. Amidon, E. P.: Nutrition Education Through the Schools. J. School Health, *14:* 63, 1944.
29. International Public Health. The Work of the Health Organization of the League of Nations in Wartime. Canad. Pub. Health J., *35:* 39–44, 1944.
30. Parran, T. and Boudreau, F. G.: The World Health Organization: Cornerstone of Peace. Am. J. Pub. Health, *36:* 1267–1272, 1946.
31. Sawyer, W. A.: Achievements of UNRRA as an International Health Organization. Am. J. Pub. Health, *37:* 41–58, 1947.
32. The United Nations International Children's Emergency Fund: Report on Child Nutrition. Lake Success, N. Y. International Children's Emergency Fund, 1947.
33. Second Annual Report of the Director-General to the FAO Conference. Washington, D. C. Food and Agriculture Organization of the United Nations. 1947.
34. Aykroyd, W. R.: Food and Nutrition—Certain International Aspects and Developments. J. Am. Dietetic Assoc., *24:* 1–4, 1948.
35. Robinson, W. D., Janney, J. H., and Grande Covian, F.: An Evaluation of the Nutritional Status of a Population Group in Madrid, Spain, During the Summer of 1941. J. Nutrition, *24:* 557–584, 1942.
36. Stuart, H. C.: Appraisal of the Nutritional State of Children in Programs of Relief Feeding. Nutrition Rev., *2:* 225–227, 1944.
37. Murdock, J. R.: Personal Communication.
38. Wilkins, W. and Sebrell, W. H.: Developments in Public Health Nutrition Appraisal. Fed. Proc., *4:* 258–263, 1945.
39. Personal Communications.
40. Adler, S. W. and Wilkins, W.: A Digest of Nutrition Conferences. New Mexico Health Officer, *12:* 1944.
41. Sebrell, W. H.: The Nature of Nutritional Diseases Occurring in the South. Milbank Mem. Fund. Quart., *17:* 358–366, 1939.
42. Fincke, M. L.: The Ascorbic Acid (Vitamin C) Metabolism of College Students. A Cooperative Study. J. Am. Dietetic Assoc., *16:* 325–328, 1940.
43. Donelson, E., Nelson, P. M., Ohlson, M. A., Pittman, M. S., Leverton, R. M., McKay, H., Kinsman, G. M., Armstrong, W., and Reynolds, M. S.: Nutritional Status of Midwestern College Women. J. Am. Dietetic Assoc., *21:* 145–147, 1945.
44. Pett, L. B., Hanley, F. W., and Perkins, E.: Haemoglobin Levels of Children in British Columbia. The Bulletin, Vancouver Med. Assoc., *22:* 128–132, 1946.
45. Pett, L. B. and Hanley, F. W.: A Nutrition Survey Among School Children in British Columbia and Saskatchewan. Canad. Med. Assoc. J., *56:* 187–192, 1947.
46. Adamson, J. D., Jolliffe, N., Kruse, H. D., Lowry, O. H., Moore, P. E., Platt, B. S.,

Sebrell, W. H., Tice, J. W., Tisdall, F. F., Wilder, R. M., and Zamecnik, P. C.: Medical Survey of Nutrition in Newfoundland. Canad. Med. Assoc. J., *52:* 227–250, 1945.

47. Abbasy, M. W.: Personal Communication.
48. Anderson, R. K. and Sandstead, H. R.: Nutritional Appraisal and Demonstration Program of the U. S. Public Health Service. J. Am. Dietetic Assoc., *23:* 101–107, 1947.
49. Burke, B. S.: Nutrition—Its Place in Our Prenatal Care Programs. Milbank Mem. Fund Quart., *23:* 54–65, 1945.
50. Tompkins, W. T.: Improved Nutrition Services for Pregnancy and Infancy. A New Approach to Nutrition Services in State Health Departments. New York. Milbank Memorial Fund, 1947.
51. Ebbs, J. H., Tisdall, F. F., and Scott, W. A.: The Influence of Prenatal Diet on the Mother and Child. J. Nutrition, *22:* 515–526, 1941.
52. King, C. G. and Menten, M. L.: The Influence of Vitamin C Level Upon the Resistance to Diphtheria Toxin. J. Nutrition, *10:* 129–140, 1935.
53. Cannon, P. R.: Importance of Proteins in Resistance to Infection. Nutrition and Public Health in the Postwar Period. Detroit, Michigan. The Children's Fund of Michigan, 1944.
54. Editorial: Nutrition in Relation to Cancer. J. A. M. A., *135:* 644, 1947.
55. Trudeau, E. L.: An Autobiography. New York. Doubleday, Page Co., 1916.
56. Edwards, H. R.: Opportunities for Application of Nutrition in the Prevention and Treatment of Tuberculosis. A New Approach to Nutrition Services in State Health Departments. New York. Milbank Memorial Fund, 1947.
57. Getting, V. A.: A Modern Nutrition Program in a State Health Department. Milbank Mem. Fund Quart., *25:* 256–262, 1947.
58. Amyot, G. F.: National, Provincial, and Local Nutrition Programs in Canada. U. S. Pub. Health Rep., *58:* 793–796, 1943.
59. Wilkins, W.: Can Health Departments Get the Facts? J. School Health, *14:* 56–59, 1944.
60. Nutrition for Young and Old. New York State Joint Legislative Committee on Nutrition, Legislative Document No. 76, 1946.
61. Blakely, R.: Nutrition Investigations and Services. Florida State Health Notes, Florida State Board of Health, *39:* 157–160, 1947.
62. Wilkins, W. and Blakely, R.: Rapid Hemoglobin Determinations on School Children. J. School Health, *16:* 196–199, 1946.
63. —— and ——: Preliminary Observations on Diurnal and Other Variations in Hemoglobin Levels. Milbank Mem. Fund Quart., *24:* 359–372, 1946.
64. Pierce, H. D., Fenton, P. F., Wilkins, W., Newland, M. E., and Budge, P. S.: Nutritional Defects Among Children in Vermont. New England J. Med., *233:* 612–617, 1945.
65. Willard, W. R.: Working for Better Nutrition in a Rural Community. Am. J. Pub. Health, *32:* 996–1000, 1942.
66. McPheeters, S. B.: The Fuller Utilization of Nutritional Knowledge by Local Health Departments. A New Approach to Nutrition Services in State Health Departments. New York. Milbank Memorial Fund, 1947.
67. Turner, M.: Nutrition and the Community. J. Am. Dietetic Assoc., *21:* 22–23, 1945.
68. Souther, S. P.: Shall Public Health Physicians Attempt to Assess Nutritional Status of School Children? Am. J. Pub. Health, *32:* 166–170, 1942.
69. Hilbert, H.: The Role of the Nurse in Improving the Nutritional Status of the Community. A New Approach to Nutrition Services in State Health Departments. New York. Milbank Memorial Fund, 1947.
70. Salcedo, J., Jr. et al.: Studies on Beriberi in an Endemic Subtropical Area. J. Nutrition, *36:* 561–577, 1948.

The National Research Council

Membership and Organization.—The National Research Council is a coöperative organization of scientific men of America, including also a representation of men of affairs interested in engineering and industry and in the basic sciences upon which the applications of science depend. Its membership is largely composed of accredited representatives of about eighty-five national scientific and technical societies. Its essential purpose is the promotion of scientific research and of the application and dissemination of scientific knowledge for the benefit of the national strength and well-being.

The Council was established at the request of the President of the United States, by the National Academy of Sciences, under its Congressional charter to coordinate the research facilities of the country for work on military problems involving scientific knowledge. In 1918, by Executive Order, it was reorganized as a permanent body for the general encouragement of scientific research.

BULLETIN
OF THE
NATIONAL RESEARCH COUNCIL
NUMBER 118 JUNE 1949

DATA ON CHEMICALS FOR CERAMIC USE

PUBLISHED BY THE NATIONAL RESEARCH COUNCIL
NATIONAL ACADEMY OF SCIENCES
WASHINGTON, D.C.

Announcement Concerning Publications
of the
National Research Council

The Proceedings of the National Academy of Sciences

is partly supported by the National Research Council which is represented officially on its Editorial Board and Executive Committee. It is open for the publication of papers to members of the National Research Council on the same terms as to members of the National Academy of Sciences.

Subscription rate for the *Proceedings* is $5 per year. Business address: Home Secretary, National Academy of Sciences, 2101 Constitution Ave., Washington 25, D. C.

The Bulletin of the National Research Council

presents monographs especially prepared by Committees of the Council or directories for general use in science compiled by the Council.

The *Bulletin* is published at irregular intervals. A discount of 20% from the list price of the *Bulletins* will be given to all who subscribe for the Series as issued, direct from the Publication Office. Numbers of the *Bulletin* are sold separately at prices based upon the cost of manufacture.

The Reprint and Circular Series of the National Research Council

renders available for purchase, at prices dependent upon the cost of manufacture, papers published or printed by or for the National Research Council. A discount of 20% from the list price will be given to all who subscribe for the Series as issued, direct from the Publication Office.

Orders for the *Bulletin* or the *Reprints and Circulars* of the National Research Council, accompanied by remittance, should be addressed: Publication Office, National Research Council, 2101 Constitution Ave., Washington 25, D. C.

A list of publications of the National Research Council with prices will be furnished upon request.

BULLETIN
OF THE
NATIONAL RESEARCH COUNCIL
NUMBER 118   JUNE 1949

DATA ON CHEMICALS FOR CERAMIC USE

FORMULAS, MOLECULAR WEIGHTS, COLORS, CRYSTAL FORMS, DENSITIES, REFRACTIVE INDICES, MELTING POINTS, BOILING POINTS, TRANSITION POINTS, DECOMPOSITION TEMPERATURES

BASED ON
National [illegible]
REPORT OF THE COMMITTEE ON CHEMICAL DATA FOR CERAMISTS,
DIVISION OF CHEMISTRY AND CHEMICAL TECHNOLOGY,
NATIONAL RESEARCH COUNCIL

ALEXANDER SILVERMAN, *Chairman*
University of Pittsburgh

HERBERT INSLEY   GEORGE W. MOREY   FREDERICK D. ROSSINI

PUBLISHED BY THE
UNIVERSITY OF PITTSBURGH
FOR THE
NATIONAL RESEARCH COUNCIL
NATIONAL ACADEMY OF SCIENCES
WASHINGTON, D.C.

PRINTED BY
THE UNIVERSITY OF PITTSBURGH
PITTSBURGH, PA., U.S.A.

PREFACE

The data contained in Bulletin 107 were taken from the Report of the Committee on Chemical Data for Ceramists which was submitted to the Division of Chemistry and Chemical Technology of the National Research Council, September 1, 1942. The revised edition brings the report up to June, 1949.

Elements and compounds are arranged alphabetically according to names. The original cards from which these data were taken have been filed and are numbered for elements and compounds according to the system employed in the International Critical Tables.

Methods of interpreting the data are indicated in the Introduction which follows.

Grateful acknowledgement is made to various manufacturers in the glass and ceramic fields whose financial support made this investigation possible; also to Dr. and Mrs. Kuan-Han Sun who served as Librarians for the committee.

HERBERT INSLEY
GEORGE W. MOREY
FREDERICK D. ROSSINI
ALEXANDER SILVERMAN, *Chairman*

CONTENTS

Preface iii

Introduction to Revised Edition vii

Introduction to Original Edition ix

Arrangement x

Abbreviations x

Substances and Properties 1

Bibliography 151

INTRODUCTION TO REVISED EDITION

The Tables of Chemical Substances and Their Physical Properties have been revised to include data in the literature from 1942 to May, 1949, inclusive. The methods of compilation and selection of the final values were essentially the same as those described in the Introduction to the Original Edition. The revised edition, in addition to the inclusion and revision of newly available properties for old substances, has many new substances (about 1000) of interest to ceramists, and has the following new features:

I. The characteristic individuality of x-ray powdered diffraction patterns of chemical substances and the simplicity of experimental techniques involved have made the x-ray data equally, if not more, important than the optical method for measuring refractive indices in the identification of chemical substances. For this reason, the three strongest x-ray powder diffraction lines, whenever available, are included in the tables. Because of the occasional difference in the results of various investigators, the order of the lines may differ somewhat. Cross references should be made to the well-known compilation of the American Society for Testing Materials (A40, A41).

II. Although the science and technology of ceramics deal essentially with silicates, recent advances have broadened the scope. The term silicones was almost unknown when the first edition appeared. Glasses containing neither silicon nor oxygen have since been developed. The revision pr sents not only a complete list of silicates, but also borates, phosphates, and fluorides. Many organo-silicon compounds are included.

III. The birth of the new synthetic elements, neptunium, plutonium, etc. has made the inclusion of these novel elements and their compounds possible. Although the application of these elements and their compounds to ceramics may not be imminent, largely because of their present scarcity, future possibilities should not be overlooked. The present revision covers the properties that have been declassified. The search for these data involved some research. Thus, the density of plutonium which had not been officially released is listed through information found buried in an entirely unrelated declassified article. Although the data may be modified if and when the complete declassification is available, the list is probably the most comprehensive to date.

IV. The formula weights of chemical substances listed have been revised on the basis of the international atomic weights of 1948 (A18).

V. Unpublished original data from G.W. Morey, P.T. Scharf, and K.-H. Sun are included.

The revised, as well as the original, tables differ from those in ordinary handbooks in the critical selection and inclusion of the original references. No compilations or treatises are free from errors, mistakes, and misprints. The present revision is probably no exception. The reader's cooperation in correcting errors is earnestly requested.

INTRODUCTION TO ORIGINAL EDITION

This compilation was carried out in two steps:

I. Collection of all available data on density, melting point, transition point, boiling point, sublimation point, decomposition temperature, refractive index, crystal form, and color of chemical substances, to 1941, that are of interest to ceramists. The collection was based on the International Critical Tables (I8), the Fifth Edition of the Landolt-Boerntein-Roth-Scheel Physikalische Chemische Tabellen (L9, L10, L11, L12), and the Tables de Constants (T2) for the period before 1933. Beginning with 1934, the search of the literature was made in Chemical Abstracts. For 1934, 1935, and 1936 formula and subject indexes of Chemical Abstracts were covered line for line to insure the inclusion of pertinent information. It was then observed that all such information was included in sections 2 (general and physical chemistry), 6 (inorganic chemistry), 8 (mineralogical and geological chemistry), 19 (glass, etc.), and 20 (cement, etc.) of Chemical Abstracts. Therefore, from 1937 to 1941 inclusive, the search was carried on by reading the above mentioned sections. Throughout the search, such important works as Gmelin (G40, G41), Mellor (M29), Pascal (P13), Abegg (A1), Friend (F65), Kelley (K12 to K15), Hall and Insley (H8, H9), Winchell (W42), Larsen and Berman (L18), and Wyckoff (W63, W63a) were consulted. With the exception of a few rare cases, all the original research papers in the period 1934 to 1941 were read by the librarian to insure correct information.

II. The choosing of each property for each substance. This is the final value given in the tables. The choice of the 'best' values was based on these considerations: (1) Contents of original papers concerning purity of materials, methods of measurement, accuracy of results, etc. (2) Reliance on investigators and laboratories of prominence. (3) Artificial or synthetic products instead of natural substances, as the latter usually contain impurities which alter the properties. (4) In general experimental density rather than density calculated from X-ray data, because small impurities alter the unit cell dimension more than they affect the experimental density. In some cases no density data were available, so they were calculated from X-ray data. Confusion in temperature scales used in the literature has been noted by Wensel (W34). No attempt has been made to correct all temperatures reported in these tables to a unified international temperature scale. It is possible that two substances which have been given the same melting point in these tables may not melt at the same temperature because of different temperature scales used by investigators. For verification, users of these tables should consult original references given in the bibliography which follows the tables.

Data given in these tables are probably the most comprehensive and authoritative to 1941 for the substances listed. Data not listed were not available in the literature. It is hoped that investigators will fill the gaps through their researches.

ARRANGEMENT

The chemical substances are arranged in alphabetical order according to the names. All prefixes are ignored in the arrangement. Thus, sodium dichromate and potassium permanganate are listed as sodium chromate, di-, and potassium manganate, per-, respectively. Similarly, fluosilicate, borosilicate, and phosphosilicate may be located under silicate, fluo-; silicate, boro-; and silicate, phospho-, respectively. If several metallic or non-metallic elements are present in a compound, they are arranged in the order of decreasing electropositivity, i.e., a silicate of sodium, calcium, and aluminum is listed as sodium calcium aluminum silicate.

As all chemical formulas of solids are empirical, expressions other than the classical or conventional may be equally desirable as long as the relative proportions of various components remain the same. Since investigators in ceramics are often interested in the original components that form the final compound, the formula of the latter is written in terms of the relative proportions of the components, i.e., $NaBO_2$, $CaSiO_3$, and $Al(PO_3)_3$ are written as $Na_2O \cdot B_2O_3$, $CaO \cdot SiO_2$, and $Al_2O_3 \cdot 3P_2O_5$, respectively. These expressions are no worse than the classical ones, since modern structure analysis indicates that in these compounds there are neither 'radicals' such as BO_2^-, $SiO_3^=$, or PO_3^-, nor oxide components such as B_2O_3, SiO_2, or P_2O_5. This method of breaking down into components becomes unfavorable for compounds such as hydroxides, carbonates, and sulfates since OH^-, $CO_3^=$, and $SO_4^=$ are known to exist in solids as sub-groups. In the latter cases, the conventional way of expressing the formulas is retained.

ABBREVIATIONS

D	Density. The number at right upper corner of the density value indicates temperature at which the density was measured in degrees C.; in the absence of such figures room temperature is assumed.
(X-ray)	After density value, indicates that the density was calculated from X-ray data.
M.P.	Melting point in °C. (All temperatures for 760 mm. pressure unless otherwise indicated.)
(Incong.)	After melting point, indicates that it is an incongruent metlting point.
T.P.	Transition point in °C.
B.P.	Boiling point in °C.
S.P.	Sublimation point in °C.
D.T.	Decomposition temperature in °C.
R.I.	Refractive index or indices, at room temperatures, for the sodium D Lines.
ω	R.I. for the ordinary ray.
ε	R.I. for the extraordinary ray.
α	Least R.I.
β	Intermediate R.I.
γ	Greatest R.I.
Nat.	Natural or native. For minerals not preceded by 'Nat.' part

or all of the physical data are for synthetic or artificial types.

I, II, III, etc., used after chemical formulas to distinguish polymorphic forms. In the literature, the symbolism for polymorphic forms differs and is confusing. In the present edition, unification is attempted. The one with the smallest Roman numeral is the most stable form at highest temperature, and the one with largest Roman numeral is the most stable form at lowest temperature. The intermediate numerals are for those stable at intermediate temperatures. For cases in which the identification of forms with respect to temperature is not clear, α, β, γ, etc. are used to differentiate various forms.

Used after the names of chemical elements and in parentheses, i.e., (I), (II), (III), etc. indicate electrovalency of the elements. They replace the old '-ous' and '-ic' nomenclature in conformity with the new Rules for Naming Inorganic Compounds (J39, F16).

Actinium - Ac - 227.05 (A20) - M.P. 1600 (A20) - S.P. >1700 (A20)

Actinium (III) sulfide - Ac_2S_3 - 550.30 - Cubic - D 6.75 (X-ray) (Z21)

Aluminium - See Aluminum

*Aluminum - Al - 26.97 - White - Cubic - D 2.699^{20} (A20) - M.P. 660.2 (A20) - B.F. 2060 (A20) - X-ray Lines 2.33, 1.22, 2.02 (A41)

Aluminum arsenate, ortho- - $Al_2O_3 \cdot As_2O_5$ - 331.76 - Colorless - Trigonal - D 3.25 (M2) - R.I. ω 1.596, ε 1.607 (M2) - X-ray Lines 1.39, 1.69, 2.15 (A41)

Aluminum borate - $Al_2O_3 \cdot B_2O_3$ (Nat. Jeremejevite) - 171.58 - Colorless - Hexagonal - D 3.3 (I8) - R.I. ω 1.640, ε - (I8)

Aluminum borate - $3Al_2O_3 \cdot B_2O_3$ - 375.46 - Colorless - Rhombic - D 3.0 (E2) - R.I. α 1.586, β 1.603, γ 1.623 (I8)

Aluminum carbide - Al_4C_3 - 143.91 - Yellow - Hexagonal - D 2.95 (S90) - M.F. >2200 (400 m.m.) (K76) - R.I. ω 2.7, ε 2.75 (W42) - X-ray Lines 2.87, 2.80, 1.66 (A40)

Aluminum cerium phosphate, hydrate - $3Al_2O_3 \cdot Ce_2O_3 \cdot 2P_2O_5 \cdot 6H_2O$ (Florencite) - 1026.10 - Trigonal - D 3.59 (I8) - R.I. ω 1.680, ε 1.685 (I8), (L12)

Aluminum chloride - Al_2Cl_6 - 266.68 - Colorless - Hexagonal - D 2.44^{25} (I8) - M.P. 192.5 (K15) - S.P. 180.2 (K13) - X-ray Lines 2.48, 5.8, 2.80 (A40)

Aluminum fluoride - AlF_3 - 83.97 - Colorless - Triclinic - D 2.882^{25} (B69) - M.P. 1040 (I8) - S.P. 1260 (R71) - R.I. 1.34 (S116) - X-ray Lines 2.13, 1.76, 1.59 (A41)

Aluminum fluoride, hydrate - $AlF_3 \cdot H_2O$ (Nat. Fluellite) - 101.99 - Colorless - Rhombic - D 2.17 (I8) - R.I. α 1.473, β 1.490, γ 1.511 (I8)

Aluminum fluoride, hydrate - $AlF_3 \cdot 3.5H_2O$ - 147.03 - White - D 1.914^{25} (L11) - D.T. 100 (M29) - X-ray Lines 5.5, 3.86, 3.28 (A40)

Aluminum fluoride, hydrate - $2AlF_3 \cdot 5H_2O$ - 258.02 - Colorless - Rhombic - $-5H_2O$ at 300 (N29) - R.I. α 1.404, β -, γ 1.425 (N29)

Aluminum hydroxide - See Aluminum oxide, hydrate

*By action of the International Union of Chemistry, Amsterdam, Holland, September 9, 1949, the official name is aluminium. Other official names are

Element 4 - Beryllium - Symbbl Be
Element 41 - Niobium - Symbol Nb
Element 43 - Technetium - Symbol Tc
Element 61 - Promethium - Symbol Pm
Element 71 - Lutetium - Symbol Lu
Element 72 - Hafnium - Symbol Hf
Element 74 - Wolfram - Symbol W
Element 85 - Astatine - Symbol At
Element 87 - Francium - Symbol Fr
Element 91 - Protactinium - Symbol Pa
Element 93 - Neptunium - Symbol Np
Element 94 - Plutonium - Symbol Pu
Element 95 - Americium - Symbol Am
Element 96 - Curium - Symbol Cm

Aluminum nitrate - $Al(NO_3)_3$ - 212.99 - Colorless - D.T. 14
(K79)

Aluminum nitrate, hydrate - $Al(NO_3)_3 \cdot 9H_2O$ - 375.14 - Colo
Rhombic - M.P. 73 (I8) - X-ray Lines 4.05, 3.01, 2.36

Aluminum oxide - Al_2O_3 (I) - 101.94 - Colorless - Hexagon
D 3.965^{28} (B65) - M.P. 2000-2030 (G18) - B.P. 2980 (R7
R.I. ω 1.768, ε 1.760 (M76) - X-ray Lines 2.08, 1.60,

Aluminum oxide - β-Alumina - Not pure Al_2O_3 - See Sodium
aluminate (A24)

Aluminum oxide - Al_2O_3 (III) - 101.94 - Colorless - Cubic
(K68) - Transition to I 750-1000 (B65) - R.I. 1.696 (M
Lines 1.40, 1.98, 2.39 (A41)

Aluminum oxide - Al_2O_3 ('δ') - 101.94 - Colorless - Hexag
D 2.40 (F11) - Transition to I 950 (F11)

Aluminum oxide - Al_2O_3 ('ζ') - 101.94 - Colorless - Octah
D 3.6 (B11) - Stable up to 1600 (B11) - R.I. 1.736 (Me

Aluminum oxide - Al_2O_3 (θ) - 101.94 - Colorless - X-ray L
2.71, 2.445 (A40)

Aluminum oxide - Al_2O_3 (κ) - 101.94 - Colorless - X-ray L
2.57, 2.115 (A40)

Aluminum oxide - Al_6O_9 - 359.76 - Yellowish gray - M.P. 2

Aluminum oxide, hydrate - $Al_2O_3 \cdot H_2O$ (Boehmite) - 119.96 -
Rhombic - D 2.97 (R13) - D.T. 450 (S91), 340 (S44) - R
β 1.624, γ - (A2) - X-ray Lines 1.85, 2.34, 1.31 (A41)

Aluminum oxide, hydrate - $Al_2O_3 \cdot H_2O$ (Diaspore) - 119.96 -
Rhombic - D 3.413 (I8) - D.T. 340 (S44) - R.I. α 1.702
γ 1.750 (I8) - X-ray Lines 2.33, 2.14, 2.08 (A41)

Aluminum oxide, hydrate - $Al_2O_3 \cdot 2H_2O$ (Bauxite) - 137.98 -
X-ray Lines 4.85, 4.34, 2.45 (A40)

Aluminum oxide, hydrate - $Al_2O_3 \cdot 3H_2O$ (Bayerite) - 155.99
- Triclinic - D 2.529^{20} (F58) - D.T. 120 (F58) - R.I.
γ - (H13) - X-ray Lines 4.76, 2.22, 4.36 (A41)

Aluminum oxide, hydrate - $Al_2O_3 \cdot 3H_2O$ (Hydrargillite or Gi
155.99 - Colorless - Monoclinic - D 2.424 (F58) - D.T.
R.I. α 1.577, β 1.577, γ 1.595 (A2) - X-ray Lines 4.85
(A40)

Aluminum phosphate, ortho- - $Al_2O_3 \cdot P_2O_5$ (I) - 243.90 - Co
Cubic - R.I. 1.465 (H103) - X-ray Lines 2.18, 1.71, 1.
defined) (A41)

Aluminum phosphate, ortho- - $Al_2O_3 \cdot P_2O_5$ (II) - 243.90 - C
hexagonal - D 2.560 (H103) - Transition to I 1460 (H10
ω 1.524, ε 1.530 (H103)

Aluminum phosphate, ortho- - $Al_2O_3 \cdot P_2O_5$ (Berlinite) - 243
Colorless - Low Berlinite transition to high berlinite
transition to low 'tridymite' form at 815; transition
high-'tridymite' form at 93, transition to upper high-
form at 130(?); transition to low 'cristobalite' form
transition to high 'cristobalite' form at 210; melting
(B27)

Aluminum phosphate, meta- - $Al_2O_3 \cdot 3P_2O_5$ - 527.82 - Colorl
- D 2.71 (H42) - X-ray Lines 4.37, 3.69, 3.40 (A41)

Aluminum phosphate, hydrate - $Al_2O_3\cdot P_2O_5\cdot 4H_2O$ (Nat. Variscite) - 315.96 - Rhombic - D 2.52 (L18) - R.I. α 1.554, β 1.571, γ 1.576 (L18)

Aluminum phosphate, hydrate - $Al_2O_3\cdot P_2O_5\cdot 4H_2O$ (Nat. Metavariscite) - 315.96 - Rhombic - D 2.54 (I8) - M.P. >1500 (I8) - R.I. α 1.551, β 1.558, γ 1.582 (I8)

Aluminum phosphate, hydrate - $Al_2O_3\cdot P_2O_5\cdot 6H_2O$ (Nat. Lucinite) - 352.00 - Rhombic - D 2.566 (I8) - R.I. α 1.563, β 1.585, γ 1.592 (I8)

Aluminum phosphate, hydrate - $Al_2O_3\cdot P_2O_5\cdot 6H_2O$ (Nat. Zepharovicht) - 352.00 - D 2.37 (I8) - M.P. >1500 (I8) - R.I. α -, β 1.55, γ - (I8)

Aluminum phosphate, hydrate - $2Al_2O_3\cdot P_2O_5\cdot 3H_2O$ (Nat. Augelite) - 399.89 - Monoclinic - D 2.77 (I8) - R.I. α 1.574, β 1.576, γ 1.588 (I8)

Aluminum phosphate, hydrate - $3Al_2O_3\cdot P_2O_5\cdot 18H_2O$ (Nat. Evansite) - 772.07 - Colorless - Amorphous - D 1.94 (L18) - R.I. 1.485 (L18)

Aluminum phosphate, hydrate - $3Al_2O_3\cdot 2P_2O_5\cdot 8H_2O$ (Nat. Sterrettite) - 733.87 - Colorless - Rhombic - D 2.36 (L21) - R.I. α 1.572, β 1.590, γ 1.601 (L21) - X-ray Lines 4.88, 4.51, 2.90 (A41)

Aluminum phosphate, hydrate - $3Al_2O_3\cdot 2P_2O_5\cdot 10H_2O$ (Nat. Coeruleolactite) - 769.90 - Colorless - Fiber - D 2.6± (L18) - R.I. ω 1.580, ε 1.588 (L18)

Aluminum phosphate, hydrate - $3Al_2O_3\cdot 2P_2O_5\cdot 13H_2O$ (Nat. Wavellite) - 823.95 - Colorless - Rhombic - D 2.4 (L18) - R.I. α 1.525, β 1.534 γ 1.552 (L18)

Aluminum phosphate, hydrate - $4Al_2O_3\cdot 3P_2O_5\cdot 30H_2O$ (Nat. Vashegyite) - 1374.12 - Colorless - Fiber - D 1.96 (L18) - R.I. α -, β 1.48, γ - (L18) - X-ray Lines 10.5, 7.2, 2.90 (A41)

Aluminum phosphate, hydrate - $5Al_2O_3\cdot 2P_2O_5\cdot 9H_2O$ (Nat. Spherite) - 955.76 - Rhombic - D 2.536 (I8) - R.I. α 1.562, β 1.576, γ 1.588 (I8)

Aluminum phosphate sulfate, hydrate - $2Al_2O_3\cdot 2P_2O_5\cdot 2SO_3\cdot 5H_2O$ (Nat. Kribergite) - 738.01 - White - D 1.92 (D41) - R.I. 1.484 (D41)

Aluminum phosphide - AlP - 57.95 - Cubic - D 2.85 (M63)

Aluminum selenide - Al_3Se_4 - 396.75 - M.P. 950 (C24)

Aluminum silicate - $Al_2O_3\cdot SiO_2$ - 162.00 - Colorless - M.P. 1545 (Incong.) (B108)

Aluminum silicate - $Al_2O_3\cdot SiO_2$ (Andalusite) - 162.00 - Colorless - Rhombic - D 3.2 (I8) - D.T. >1325, <1410 (K79) - R.I. α 1.632, β 1.638, γ 1.643 (I8) - X-ray Lines 4.52, 2.17, 1.47 (A41)

Aluminum silicate - $Al_2O_3\cdot SiO_2$ (Sillimanite) - 162.00 - Colorless - Rhombic - D 3.247^{28} (F49) - Transition to Andalusite 1490(?) (N19) - D.T. >1345, <1550 (K79) - R.I. α 1.659, β 1.660, γ 1.680 (L18) X-ray Lines 3.423, 3.368, 2.204 (A40)

Aluminum silicate - $Al_2O_3\cdot SiO_2$ (Cyanite) - 162.00 - Colorless - Triclinic - D 3.6 (I8) - D.T. >1000, <1325 (K79) - R.I. α 1.712, β 1.720, γ 1.728 (I8) - X-ray Lines 1.95, 1.38, 3.33 (A41)

Aluminum silicate - $3Al_2O_3\cdot 2SiO_2$ (Mullite) - 425.94 - Colorless - Rhombic - D 3.156^{28} (I8) - M.P. 1830 (Incong.) (S78) - R.I. α 1.638, β 1.642, γ 1.653 (N34) - X-ray Lines 3.44, 2.55, 2.22 (A41)

Aluminum silicate - $3Al_2O_3 \cdot 2SiO_2$ (Glass) - 425.94 - Colorle
D 2.54 (S52)

Aluminum silicate, boro-, hydrate - $8Al_2O_3 \cdot B_2O_3 \cdot 6SiO_2 \cdot H_2O$ -
Rhombic - D 3.3 (I8) - R.I. α 1.678, β 1.686, γ 1.689 (I

Aluminum silicate, fluo- - $2AlFO \cdot SiO_2$ (Nat. Topaz) - 184.00
- D 3.58 (I8) - R.I. α 1.619, β 1.620, γ 1.627 (I8)

Aluminum silicate, fluo- - $2AlF_3 \cdot 3SiF_4$ - 480.12 - White - X
3.52, 1.76, 2.11 (A40)

Aluminum silicate, hydrate - $Al_2O_3 \cdot 2SiO_2 \cdot 2H_2O$ (Dickite) - 2
Colorless - Rhombic - D 2.676 (H36) - D.T. 500 (Y5) - R.
1.561, β 1.563, γ 1.566 (Y5) - X-ray Lines 7.2, 3.58, 2.

Aluminum silicate, hydrate - $Al_2O_3 \cdot 2SiO_2 \cdot 2H_2O$ (Kaolinite) -
Colorless - Monoclinic - D 2.6 (I8) - $-2H_2O$ at 450 (S43)
1.561, β 1.565, γ 1.567 (I8) - X-ray Lines 7.2, 2.33, 3.

Aluminum silicate, hydrate - $Al_2O_3 \cdot 2SiO_2 \cdot 2H_2O$ (Nat. Metahal
258.09 - Colorless - X-ray Lines 7.5, 4.44, 1.49 (A41)

Aluminum silicate, hydrate - $Al_2O_3 \cdot 2SiO_2 \cdot 2H_2O$ (Nat. Nacrite
258.09 - Colorless - X-ray Lines 7.15, 3.58, 2.42 (A41)

Aluminum silicate, hydrate - $Al_2O_3 \cdot 2SiO_2 \cdot 4H_2O$ - 294.12 - He
plate - D 2.12 (X-ray) (A7) - R.I. 1.490 (A7) - X-ray Li
4.46, 3.40 (A41)

Aluminum silicate, hydrate - $Al_2O_3 \cdot 2SiO_2 \cdot 4H_2O$ (Nat. Newtoni
294.12 - Colorless - Tetragonal - D 2.37 (I8) - R.I. ω 1
ε 1.580 (I8)

Aluminum silicate, hydrate - $Al_2O_3 \cdot 4SiO_2 \cdot H_2O$ (Nat. Pyrophyl
360.20 - Colorless - Rhombic - D 2.85 (I8) - $-H_2O$ at >60
R.I. α 1.552, β 1.588, γ 1.600 (I8) - X-ray Lines 3.04,
(A41)

Aluminum silicate, hydrate - $Al_2O_3 \cdot 6SiO_2 \cdot 18H_2O$ (Nat. Termie
786.59 - Colorless - D 1.21(?) (L18) - R.I. 1.403 (L18)

Aluminum silicate, hydrate - $2Al_2O_3 \cdot 3SiO_2 \cdot 5H_2O$ (Nat. Kochit
474.14 - Colorless - Cubic - D 2.93 (L18) - R.I. 1.590 (

Aluminum silicate, hydrate - $2Al_2O_3 \cdot 6SiO_2 \cdot 3H_2O$ (Nat. Ton) -
R.I. 1.53 (G4)

Aluminum silicate, hydrate - $2Al_2O_3 \cdot 6SiO_2 \cdot 5H_2O$ (Nat. Anauxi
654.32 - Colorless - Monoclinic - R.I. α 1.559, β 1.564,
(L18)

Aluminum silicate, hydrate - $2Al_2O_3 \cdot 7SiO_2 \cdot 7H_2O$ (Nat. Takizo
750.41 - R.I. 1.515 (J23)

Aluminum silicate, hydrate - $3Al_2O_3 \cdot 8SiO_2 \cdot 7H_2O$ (Nat. Hydroc
- 912.41 - R.I. α 1.479, β 1.710, γ 1.810 (L9)

Aluminum sulfate - $Al_2(SO_4)_3$ - 342.14 - Colorless - D 2.71
D.T. 757 (760 m.m.) (K17) - R.I. 1.47 (Mean) (B91) - X-r
3.50, 5.8, 2.65 (A40)

Aluminum sulfate, hydrate - $Al_2(SO_4)_3 \cdot 18H_2O$ (Alunogenite) -
Colorless - Monoclinic - D 1.691 (I8) - R.I. α 1.474,
γ 1.483 (I8) - X-ray Lines 4.42, 3.95, 2.48 (A40)

Aluminum sulfide - Al_2S_3 - 150.14 - Yellow - Hexagonal - D
- M.P. 1100 (I8) - S.P. 1550 (in N_2) (I8) - X-ray Lines
1.86 (A40)

Aluminum tantalate - $3Al_2O_3 \cdot 2Ta_2O_5$ (Nat. Calogerassite) - 1
Hexagonal prism - D 7.10 (G88)

Aluminum tantalate - $3Al_2O_3 \cdot 2Ta_2O_5$ (Nat. Simpsonite) - 1189.34 - Hexagonal - D 6.70 (K25) - R.I. ω 2.0402, ε 1.9944 (K25) - X-ray Lines 1.638, 1.387, 1.0210 (K25)
Aluminum thallium (I) fluoride - $AlF_3 \cdot TlF$ - 307.36 - X-ray Lines 3.14, 2.39, 2.37 (A41)
Aluminum thallium (I) fluoride - $AlF_3 \cdot 2TlF$ - 530.75 - X-ray Lines 3.00, 2.87, 2.42 (A41)
Aluminum titanite - $Al_2O_3 \cdot TiO_2$ - 181.84 - M.P. 1860 (B152) - R.I. α 1.975, β -, γ 2.015 (All for Li-Line) (B152)

Americium - Am - Synthetic element with mass numbers 241 and 242 for the known isotopes (S45)
Americium (III) sulfide - Am_2S_3 - Cubic - D 8.50 (X-ray) (Z21)

Ammonia - NH_3 - 17.032 - Colorless Gas - D 0.817^{-79} (I8) - M.P. -78.0 (T12) - B.P. -33.45 (T12)
Ammonia, heavy - ND_3 (99% Heavy Hydrogen) - 20.049 - Colorless Gas - D 1.174 (T12) - M.P. -74.2 (T12) - B.P. -30.9 (T12)
Ammonium aluminate, fluo- - $NH_4F \cdot AlF_3$ - 121.01 - Tetragonal - D 2.02 (L10) - D.T. 350 to AlF_3 (I8)
Ammonium aluminate, fluo- - $3NH_4F \cdot AlF_3$ - 195.09 - Cubic - D 1.84 (X-ray) (S119) (F53) - X-ray Lines 4.85, 2.100, 2.423 (A40)
Ammonium aluminum sulfate - $(NH_4)_2SO_4 \cdot Al_2(SO_4)_3$ - 474.28 - Colorless - Hexagonal - D 2.45 (S13) - D.T. 420-450 (G41)
Ammonium antimonate, fluo- - $NH_4F \cdot SbF_5$ - 253.80 - Rhombohedron - D 3.205^{18} (L13) - M.P. 315 (L13) - R.I. ω 1.391, ε 1.394±.001 (L13)
Ammonium arsenate, ortho- - $3(NH_4)_2O \cdot As_2O_5$ - 386.06 - D.T. 100 (879.0 m.m.) (M15)
Ammonium arsenate, hydrate - $(NH_4)_2O \cdot As_2O_5 \cdot 2H_2O$ - 317.93 - Tetragonal - D 2.340^{20} (M15) - R.I. ω 1.577, ε 1.522 (I8)
Ammonium arsenate, hydrate - $2(NH_4)_2O \cdot As_2O_5 \cdot H_2O$ - 352.00 - Monoclinic - D 1.989 (I8) - D.T. 149.5 (660.6 m.m.) (M15)
Ammonium beryllium fluoride - $2NH_4F \cdot BeF_2$ - 121.10 - Rhombic - D 1.683^{30} (R10)
Ammonium borate, fluo- - $NH_4F \cdot BF_3$ - 104.86 - Rhombic - D 1.851^{17} (I8) - X-ray Lines 4.50, 3.55, 3.18 (A40)
Ammonium borate, hydrate - $(NH_4)_2O \cdot 5B_2O_3 \cdot 8H_2O$ - 544.41 - Colorless - Rhombic - R.I. α 1.490, β 1.431, γ 1.436 (G41)
Ammonium calcium phosphate, hydrate - $(NH_4)_2O \cdot 2CaO \cdot P_2O_5 \cdot 14H_2O$ - 558.42 - Monoclinic - D 1.561^{15} (I8)
Ammonium calcium sulfate - $(NH_4)_2SO_4 \cdot 2CaSO_4$ - 404.44 - Colorless - Cubic - R.I. 1.532 (G1)
Ammonium carbonate, bi- - NH_4HCO_3 - 79.06 - Colorless - Rhombic - D 1.586 (L9) - M.P. 106 (in capillary tube) (T21) - D.T. 80 (760 m.m.) (K14) - R.I. α 1.4227, β 1.5358, γ 1.5545 (G41) - X-ray Lines 2.99, 5.3, 4.02 (A40)
Ammonium chlorate - NH_4ClO_3 - 101.50 - Colorless - Monoclinic needle - M.P. 102 (K79)
Ammonium chlorate, per- - NH_4ClO_4 (I) - 117.50 - Colorless - Cubic - D 1.73 (X-ray) (H49) - X-ray Lines 4.40, 3.82, 2.70 (Form not defined) (A41)

Ammonium chlorate, per- - NH_4ClO_4 (II) - 117.50 - Colorless
- D 1.9518^{28} (W59) - Transition to I 240 (H49) - R.I. α
β 1.4828, γ 1.4868 (W58) - X-ray Lines 4.61, 3.60, 3.25

Ammonium chloride - NH_4Cl (I) - 53.50 - Colorless - Cubic -
(X-ray) (B16) - M.P. 550 (66 atm.) (K79) - T.P. 184 (K79
340 (B121), (S71) - X-ray Lines 2.73, 1.58, 1.93 (Form n
defined) (A41)

Ammonium chloride - NH_4Cl (II) (Salammoniac) - 53.50 - Colo
Cubic - D 1.5274^{25} (W57) - Transition to I 184.5 (G41) -
(1 atm.) (K79) - R.I. 1.63851^{28} (W57) - X-ray Lines 2.73
3.874 (A40)

Ammonium chromate - $(NH_4)_2O\cdot CrO_3$ - 152.09 - Yellow - Monocl
1.89 (L9) - X-ray Lines 4.80, 3.18, 5.6 (A40)

Ammonium chromate, di- - $(NH_4)_2O\cdot 2CrO_3$ - 252.10 - Yellowish
Monoclinic - D 2.15 (I8) - T.P. -2.40 (K57) - X-ray Line
3.37, 6.6 (A40)

Ammonium chromium (III) fluoride - $3NH_4F\cdot CrF_3$ - 220.13 - X-
2.26, 1.73, 1.20 (A41)

Ammonium fluoride - NH_4F - 37.04 - Colorless - Hexagonal -
(W57) - R.I. ω 1.378, ϵ 1.390 (M78) - X-ray Lines 3.85,
(A40)

Ammonium germanate, fluo- - $2NH_4F\cdot GeF_4$ - 222.68 - Hexagonal
2.564^{28} (L11)

Ammonium hafnate, fluo- - $3NH_4F\cdot HfF_4$ - 365.72 - Cubic - R.I
(L12)

Ammonium hydrogen fluoride - NH_4HF_2 - 57.05 - Orthorhombic
I24.6 (M78) - R.I. α 1.368, β 1.385, γ 1.387 (M78)

Ammonium hydroxide - NH_4OH - 35.05 - Colorless - Needle - M
(E15)

Ammonium iron (III) fluoride - $3NH_4F\cdot FeF_3$ - 223.97 - Cubic
(M55) - X-ray Lines 4.85, 2.100, 2.423 (A40)

Ammonium magnesium phosphate, hydrate - $(NH_4)_2O\cdot 2MgO\cdot P_2O_5\cdot$ I
490.87 - Colorless - Orthorhombic - D 1.72 - $-12H_2O$ at <
- R.I. α 1.495, β 1.496, γ 1.504 (L12)

Ammonium manganate, per- - NH_4MnO_4 - 136.97 - Rhombic - D 2
(I8) - D.T. 110 (C58)

Ammonium manganese (III) fluoride - $2NH_4F\cdot MnF_3$ - 186.01 - F
R.I. α 1.46, β -, γ 1.50 (L12)

Ammonium molybdate - $(NH_4)_2O\cdot MoO_3$ - 196.03 - Colorless - Mo
D 2.276 (B51)

Ammonium molybdate, fluo- - $3NH_4F\cdot MoO_3$ - 255.07 - Cubic - D
(X-ray) (S119), (F53)

Ammonium nitrate - NH_4NO_3 (I) - 80.05 - Colorless - Cubic -
(H41) - M.P. 169.6 (I8) - D.T. 230 (760 m.m.) (H73) - R.
1.530^{130} (H40)

Ammonium nitrate - NH_4NO_3 (II) - 80.05 - Colorless - Tetrag
D 1.64 (H41) - Transition to I 125 (G41) - R.I. ω 1.509
ϵ 1.585^{83} (H40)

Ammonium nitrate - NH_4NO_3 (III) - 80.05 - Colorless - Rhomb
D 1.66 (H41) - Transition to II 83.5 (G41) - R.I. α 1.46
β 1.543^{40}, γ 1.600^{40} (H40)

Ammonium nitrate - NH_4NO_3 (IV) - 80.05 - Colorless - Rhombic - D 1.714^{32} (C46) - Transition to III 32 (G41) - R.I. α 1.41, β 1.61, γ 1.64 (B107)

Ammonium nitrate - NH_4NO_3 (V) - 80.05 - Colorless - Hexagonal - D 1.74 (H41) - Transition to IV -17 (G41) - R.I. ω 1.493^{-25}, ε 1.623^{-25} (H40)

Ammonium oxide - $(NH_4)_2O$ - 52.08 - M.P. -78.88 (E15)

Ammonium phosphate, meta- - $(NH_4)_2O \cdot P_2O_5$ - 194.04 - Colorless - Monoclinic - D 1.811^{25} (B54) - R.I. α 1.490, β -, γ 1.505 (K32)

Ammonium phosphate, pyro- - $2(NH_4)_2O \cdot P_2O_5$ - 246.12 - Colorless - D 1.543^{18} (B54)

Ammonium phosphate, ortho- - $3(NH_4)_2O \cdot P_2O_5$ - 298.20 - Colorless - D 1.480^{-78} (B54)

Ammonium phosphate, hydrate - $(NH_4)_2O \cdot P_2O_5 \cdot 2H_2O$ - 230.07 - Colorless - Tetragonal - D 1.798^{25} (B54) - T.P. 18.9 (K57) - R.I. ω 1.525, ε 1.479 (I8) - X-ray Lines 3.07, 5.3, 3.76 (A40)

Ammonium phosphate, hydrate - $2(NH_4)_2O \cdot P_2O_5 \cdot H_2O$ - 264.14 - Colorless - Monoclinic - D 1.605^{17} (B54) - R.I. α -, β 1.52-1.54, γ - (G41) - X-ray Lines 5.0, 3.20, 3.04 (A40)

Ammonium rhenate - $(NH_4)_2O \cdot Re_2O_7$ - 536.70 - Rhombic - D 3.53 (S68)

Ammonium scandium fluoride - $3NH_4F \cdot ScF_3$ - 213.22 - Tetragonal - R.I. ω <1.47, ε < ω (L12)

Ammonium selenate - $(NH_4)_2O \cdot SeO_3$ - 179.04 - Monoclinic - D 2.194 (I8) - R.I. α 1.5607, β 1.5630, γ 1.5846 (I8)

Ammonium silicate, fluo- - $2NH_4F \cdot SiF_4$ (Cryptohalite) - 178.14 - Cubic - D 2.152 (G56) - R.I. 1.370 (I8)

Ammonium silicate, fluo- - $2NH_4F \cdot SiF_4$ - 178.14 - Trigonal Hexagonal - D 2.01 (I8) - R.I. ω 1.406, ε 1.391 (L12) - X-ray Lines 4.85, 2.42, 2.09 (A40)

Ammonium sodium phosphate, hydrate - $NH_4NaHPO_4 \cdot 4H_2O$ (Microsmic Salt) - 209.13 - Colorless - Monoclinic - D 1.574 (I8) - D.T. 79 (I8) - R.I. α 1.439, β 1.442, γ 1.469 (I8)

Ammonium sulfate - $(NH_4)_2SO_4$ (Mascagnite) - 132.15 - Colorless - Rhombic - D 1.764 (J28) - M.P. 513 (K22) - T.P. -49.71 (K57) - R.I. α 1.5209, β 1.5230, γ 1.5330 (I8)

Ammonium sulfate, bi- - NH_4HSO_4 - 115.11 - Colorless - Rhombic - D 1.78 (I8) - M.P. 146.9 (I8) - B.P. 490 (I8) - R.I. α 1.463, β 1.473, γ 1.510 (W42) - X-ray Lines 4.75, 3.69, 2.61 (A40)

Ammonium sulfate, per- - $(NH_4)_2S_2O_8$ - 228.21 - Monoclinic - D 1.982 (I8) - D.T. 120 (I8) - R.I. α 1.4981, β 1.5016, γ 1.5866 (I8)

Ammonium sulfide, bi- - NH_4HS - 51.11 - Colorless - Tetragonal - D 1.18 (W38) - R.I. ω >1.74, ε <1.74 (W37)

Ammonium tellurate - $(NH_4)_2O \cdot TeO_3$ - 227.69 - D 3.01 (I8)

Ammonium tungsten phosphate, hydrate - $3(NH_4)_2O \cdot 6WO_3 \cdot P_2O_5 \cdot 9H_2O$ - 1851.86 - X-ray Lines 3.37, 2.92, 2.48 (A40)

Ammonium uranium (VI) carbonate - $2(NH_4)_2O \cdot UO_3 \cdot 3CO_2$ - 522.26 - Monoclinic - R.I. α 1.600, β 1.600±0.001, γ 1.625 (L12)

Ammonium vanadate, meta- - $(NH_4)_2O \cdot V_2O_5$ - 233.98 - D 2.326 (M29) - D.T. 200 (D37) - X-ray Lines 3.17, 4.14, 4.92 (A40)

Ammonium vanadium (III) fluoride - $3NH_4F \cdot VF_3$ - 219.07 - X-ray Lines 2.26, 1.74, 1.21 (A41)

Ammonium vanadate, orthothio- - $3(NH_4)_2S \cdot V_2S_5$ - 466.67 -
Rhombic - D 1.620 (K100)
Ammonium zinc arsenate - $(NH_4)_2O \cdot 2ZnO \cdot As_2O_5$ - 444.66 - X
4.85, 4.55, 3.29 (A40)
Ammonium zinc fluoride - $NH_4F \cdot ZnF_2$ - 140.42 - R.I. 1.70
Ammonium zinc phosphate - $(NH_4)_2O \cdot 2ZnO \cdot P_2O_5$ - 356.80 - C
X-ray Lines 3.17, 6.25, 4.62, (A40)
Ammonium zirconium fluoride - $3NH_4F \cdot ZrF_4$ - 278.34 - Colo
octahedron - D 2.20 (H24) - R.I. 1.433 (I8)

Antimony - Sb - 121.76 - Bluish White - Hexagonal - D 6.
M.P. 630.5 (A20) - T.P. 413 (K79) - B.P. 1440 (A20) -
3.08, 2.31, 2.14 (A41)
Antimony arsenate - $SbAsO_4$ - 260.67 - X-ray Lines 3.20,
(A40)
Antimony (III) chloride - $SbCl_3$ - 228.13 - Colorless - F
3.140^{20} (I8) - M.P. 72.9 (B70) - T.P. 65.0, 69.5 (K21
(I8) - X-ray Lines 5.00, 2.20, 1.71 (A40)
Antimony (V) chloride - $SbCl_5$ - 299.04 - Colorless Liqui
$2.349^{20.9}$ (S63) - M.P. 4.0 (K15) - B.P. 106.5 (76 m.m
1.601^{14} (I8)
Antimony (III) chloride, oxy- - SbOCl - 173.22 - Colorle
(I8) - X-ray Lines 3.27, 3.10, 2.55 (A40)
Antimony (III) fluoride - SbF_3 - 178.76 - Colorless - Rh
4.385^{28} (B69) - M.P. 292 (I8) - B.P. 376 (R68) - X-ra
3.40, 4.91 (A40)
Antimony (V) fluoride - SbF_5 - 216.76 - Colorless Liquid
(I8) - M.P. 7 (I8) - B.P. 149.5 (I8)
Antimony (III,V) fluoride - $2SbF_3 \cdot SbF_5$ - 574.28 - D 4.18
M.P. 290 (I8) - B.P. 390 (I8)
Antimony (III) iodide - SbI_3 - 502.52 - Ruby Red - Hexag
Monoclinic - D 4.848^{28} (I8) - M.P. 170.3 (B70) - T.P.
(I8) - B.P. 401 (I8) - R.I. ω 2.78, ε 2.36 (All for L
- X-ray Lines 3.30, 2.54, 2.14 (A40)
Antimony (V) iodide - SbI_5 - 756.36 - Brown - M.P. 79 (I
Antimony (III) oxide - Sb_4O_6 (I) (Valentinite) - 583.04
Rhombic - D 5.67 (I8) - M.P. 655 (M5) - B.P. 1456 (H6
α 2.18, β 2.35, γ 2.35 (I8) - X-ray Lines 3.08, 10.85
Antimony (III) oxide - Sb_4O_6 (II) (Senarmontite) - 583.0
- Cubic - D 5.19^{25} (S61) - Transition to I 570 (R32)
(K79) - B.P. 1455 (K79) - R.I. 2.087 (I8) - X-ray Lin
3.18, 1.67 (A41)
Antimony (III) oxide - Sb_2O_3 (Glass) - 291.52 - Colorles
Yellow - D 5.18+ (Quenched Sample) (K70) - R.I. 2.090
Sample) (K70)
Antimony (V) oxide - Sb_4O_{10} - 647.04 - Yellow - Cubic -
(X-ray) (S60) - D.T. (in 1/5 atm. O_2) 380 (K79) - -O
- X-ray Lines 6.0, 3.10, 2.97 (A40); 1.54, 1.81, 1.17
Antimony (III,V) oxide - $Sb_2O_3 \cdot Sb_2O_5$ (Cervantite) - 615.
less - Cubic - D 6.59 (D21) - Decomposes to Sb_2O_3 >10
R.I. 2.0 (I8) - X-ray Lines 3.07, 3.44, 1.719 (A40)

Antimony (V) oxide, hydrate - $Sb_2O_5 \cdot H_2O$ - 341.54 - White - D 6.6 - X-ray Lines 1.54, 1.81, 1.14 (A41)
Antimony (V) oxide, hydrate - $Sb_2O_5 \cdot 3H_2O$ - 377.57 - X-ray Lines 1.55, 1.81. 1.18 (A41)
Antimony selenide - SbSe - 200.72 - M.P. 542 (I8)
Antimony (III) selenide - Sb_2Se_3 - 480.40 - Gray - M.P. 620 (K79)
Antimony (III) sulfate - $Sb_2(SO_4)_3$ - 531.72 - Colorless - Prism - D 3.625^4 (I8)
Antimony (III) sulfide - Sb_4S_6 (Stibenite) - 679.44 - Orange Red - Rhombic - D 4.64 (I8) - M.P. 546 (K15) - R.I. α 3.194, β 4.046, γ 4.303 (I8) - X-ray Lines 3.55, 1.94, 1.69 (A41)
Antimony (III) sulfide, oxy- - $2Sb_2S_3 \cdot Sb_2O_3$ (Nat. Kermesite) - 970.96 - Cherry Red - Monoclinic - D 4.6 (I8) - M.P. 520 (K79) - R.I. α 2.74, β -, γ - (All for Li-Line) (I8) - X-ray Lines 3.14, 2.92, 2.70 (A41)
Antimony (III) tantalate - $Sb_2O_3 \cdot Ta_2O_5$ (Nat. Stibiotantalite) - 764.96 - X-ray Lines 3.14, 2.96, 1.89 (A41)
Antimony (III) telluride - Sb_2Te_3 - 626.35 - Gray - M.P. 650 (K79)

Arsenic - As - 74.91 - Steel Gray - Rhombohedral (A20) - D 5.73^{20} (A20) - M.P. 814 (36 atm.) (A20) - S.P. 610 (A20) - X-ray Lines 2.74, 1.87, 2.04 (A41)
Arsenic - As (Glassy) - 74.91 - Silver White - D 4.73 (S98)
Arsenic borate - See Boron arsenate
Arsenic (III) chloride - $AsCl_3$ - 181.28 - Colorless Liquid - D 2.163^{20} (Liquid) (I8) - M.P. -16 (K79) - B.P. 130.4 (7 2 m.m.) (B70) - R.I. 1.6040 (M29)
Arsenic (V) chloride - $AsCl_5$ - 252.19 - Yellow - M.P. -40 (I8)
Arsenic (III) fluoride - AsF_3 - 131.91 - Colorless Liquid - D 2.666^0 (I8) - M.P. -8.5 (M29) - B.P. 64 (R68)
Arsenic (V) fluoride - AsF_5 - 169.91 - Colorless Gas - M.P. -79.8 (R66) - B.P. -52.8 (R66)
Arsenic (III) iodide - AsI_3 - 455.67 - Yellowish Red - Hexagonal - D 4.39^{13} (I8) - M.P. 141.8 (B70) - B.P. 400 (K79) - R.I. ω 2.59, ε 2.23 (6560 A.) (W42) - X-ray Lines 3.21, 3.59, 2.53 (A40)
Arsenic (V) iodide - AsI_5 - 709.51 - Brown - Monoclinic - D 3.93 (I8) - M.P. 70 (M29) (L9)
Arsenic (III) oxide - As_4O_6 (Claudetite) - 395.64 - Colorless - Monoclinic - D 3.85-4.15 (L18) - M.P. 312.6 (M5) - B.P. 457.2 (M5) - R.I. α 1.871, β 1.92, γ 2.01 (I8) - X-ray Lines 3.19, 1.55, 1.95 (A41)
Arsenic (III) oxide - As_4O_6 (Nat. Arsenolite) - 395.64 - Colorless - Cubic - D 3.70 (L18) - M.P. 275 (K79) - R.I. 1.755 (L18) - X-ray Lines 3.19, 1.068, 2.53 (A41)
Arsenic (III) oxide - As_4O_6 ('a') - 395.64 - Colorless - Cubic - Metastable M.P. 272.1 - Transition to Claudetite 221 (S70) - T.P. -13 (S21) - X-ray Lines 1.068, 0.965, 3.20 (Form not defined) (A41)
Arsenic (III) oxide - As_4O_6 ('c') - 395.64 - Colorless - Metastable M.P. 289.6 - Claudetite Transition to this form 258.4 (S70)

Arsenic (III) oxide - As_2O_3 (Glass) - 197.82 - Colorless or
Yellow - D 3.701 (Quenched Sample) (M77) - R.I. 1.8141 (M
Arsenic (V) oxide - As_4O_{10} - 459.64 - Colorless - D 4.09 (I8
400 (M29) - X-ray Lines 4.88, 3.58, 3.40 (A40)
Arsenic (III) selenide - As_2Se_3 - 386.70 - Brown - M.P. 260
Arsenic sulfide - As_4S_3 (Dimorphite) - 395.84 - Yellow - Rho
3.60^{18} (I8) - M.P. >200 (L9)
Arsenic sulfide - As_2S_2 (I) (Realgar) - 213.95 - Black - Mon
D 3.254^{18} (I8) - M.P. 320 (K79) - B.P. 565 (I8) - X-ray L
5.41, 6.00, 3.15 (A41)
Arsenic sulfide - As_2S_2 (II) - 213.95 - Orange Red - Monocli
3.506^{18} (I8) - Transition to I 267 (I8) - R.I. α 2.538, β
γ 2.704 (L18)
Arsenic (III) sulfide - As_2S_3 (I) - 246.02 - M.P. 310 (K79)
707 (I8)
Arsenic (III) sulfide - As_2S_3 (II) (Orpiment) - 246.02 - Yel
Monoclinic - D 3.43 (I8) - Transition to I 170 (I8) - R.I
β 2.81, γ 3.02 (All for Li-Line) (L18) - X-ray Lines 4.77
2.71 (A41)
Arsenic (III) telluride - As_2Te_3 - 532.65 - M.P. 362 (K79)

Astatine - $_{85}At$ - Synthetic element with mass numbers 210, 2
215, 216, and 217 for the known isotopes (S45)

Barium - Ba - 137.36 - Silvery White - Cubic - D 3.5^{20} (A20)
704 (A20) - T.P. 370 (K79) - B.P. 1640 (A20) - X-ray Line
2.050, 1.339 (A40)
Barium aluminate - $BaO \cdot Al_2O_3$ - 255.30 - White - Cubic and He
(W5) - D 3.99^{20} (T40) - M.P. 2000 (W18) - R.I. 1.683 (T40
Lines 3.16, 4.55, 2.61 (A41)
Barium aluminate - $BaO \cdot 6Al_2O_3$ - 765.00 - Hexagonal - D 3.637
- M.P. 1860 (T45) - R.I. ω 1.702, ε 1.694 (T45)
Barium aluminate - $3BaO \cdot Al_2O_3$ - 562.02 - Gray White - Tabula
4.54^{20} (T40) - R.I. β 1.735, α-γ=0.009 (T40)
Barium aluminate, fluo-, hydrate - $3BaF_2 \cdot 2AlF_3 \cdot H_2O$ - 712.04
Isotropic - D 4.43 (N24) - R.I. 1.455±.003 (N24)
Barium aluminate, hydrate - $BaO \cdot Al_2O_3 \cdot H_2O$ - 273.32 - Colorle
Cubic - R.I. 1.644 (C13) - X-ray Lines 2.79, 3.42, 2.28 (
Barium aluminate, hydrate - $BaO \cdot Al_2O_3 \cdot 2H_2O$ - 291.33 - Colorl
R.I. α 1.610, γ 1.613 (C13) - X-ray Lines 3.20, 3.50 (C13
Barium aluminate, hydrate - $BaO \cdot Al_2O_3 \cdot 4H_2O$ - 327.36 - Colorl
R.I. α 1.625, β 1.628, γ 1.650 (C13) - X-ray Lines 4.91,
2.15 (C13)
Barium aluminate, hydrate - $BaO \cdot Al_2O_3 \cdot 7H_2O$ - 381.41 - Colorl
M.P. <120 (C13) - R.I. α 1.538, γ 1.556 (C13)
Barium aluminate, hydrate - $1.1BaO \cdot Al_2O_3 \cdot 6H_2O$ - 388.93 - Col
R.I. α 1.535, γ 1.540 (C13) - X-ray Lines 3.61, 10.7, 5.3
Barium aluminate, hydrate - $2BaO \cdot Al_2O_3 \cdot 5H_2O$ - 498.74 - Color
3.42 (C13) - R.I. α 1.642, β 1.655, γ 1.676 (C13) - X-ray
6.31, 3.03, 2.37 (C13)

Barium aluminum phosphate, hydrate - $2BaO \cdot 3Al_2O_3 \cdot 2P_2O_5 \cdot 7H_2O$ (Nat. Gorceixite) - 1022.57 - R.I. ω 1.6253, ε>ω (L12)

Barium aluminum silicate - $BaO \cdot Al_2O_3 \cdot 2SiO_2$ (I) (Celsian) - 375.42 - Hexagonal - D 3.302 (D25) - M.P. 1720 (D25) - R.I. α 1.5712, β -, γ - (D25)

Barium aluminum silicate - $BaO \cdot Al_2O_3 \cdot 2SiO_2$ (II) (Celsian) - 375.42 - Monoclinic - D 3.37 (I8) - R.I. α 1.587, β 1.593, γ 1.600 (E21)

Barium aluminum silicate - $BaO \cdot Al_2O_3 \cdot 5SiO_2$ (Harmotome) - 455.60 - Colorless - Monoclinic - R.I. α 1.503, β 1.506, γ 1.508 (L9) - X-ray Lines 8.1, 7.2, 6.3 (A41)

Barium aluminum silicate - $4BaO \cdot Al_2O_3 \cdot 7SiO_2$ (Barylite) - 1135.80 - Colorless - Rhombic - D 4.03 (I8) - R.I. α 1.681, β 1.685, γ 1.695 (I8)

Barium arsenate, ortho- - $3BaO \cdot As_2O_5$ - 689.90 - Colorless, Transparent - Needle - D 5.10 (G82) (G84) - M.P. 1605 (G82) (G84)

Barium arsenate, hydrate - $2BaO \cdot As_2O_5 \cdot 3H_2O$ - 590.59 - Colorless - Rhombic - D 3.93^{18} (I8) - R.I. 1.635 (Mean) (H37)

Barium beryllium fluoride - $BaF_2 \cdot BeF_2$ - 222.38 - White - Rhombic - D 4.170^{30} (R10) - M.P. 1000 (S97)

Barium beryllium fluoride - $BaF_2 \cdot 2BeF_2$ - 269.40 - White - M.P. 900± (S97)

Barium beryllium silicate - $BaO \cdot 2BeO \cdot 2SiO_2$ (Nat. Barylite) - 323.52 - Colorless - Rhombic - D 4.03 (A21) - R.I. α 1.691, β 1.696, γ 1.703 (A21)

Barium borate - $BaO \cdot B_2O_3$ - 223.00 - Colorless - Needle - T.P. 100-400 (L45) - R.I. ω 1.667, ε 1.528 (L45) - X-ray Lines 3.60, 2.68, 2.54 (Form I); 3.50, 3.58, 2.06 (Form II) (L45)

Barium borate - $BaO \cdot B_2O_3$ (Glass) - 223.00 - Colorless - R.I. 1.66 (L45)

Barium borate - $BaO \cdot 2B_2O_3$ - 292.64 - Colorless - Needle - M.P. 900 (L45) - R.I. α 1.595, β 1.610, γ 1.668 (L45) - X-ray Lines 3.13, 3.39, 6.15 (L45)

Barium borate - $BaO \cdot 2B_2O_3$ (Glass) - 292.64 - Colorless - R.I. 1.615 (L45)

Barium borate - $BaO \cdot 3B_2O_3$ - 362.28 - Colorless - M.P. 740 (C11)

Barium borate - $BaO \cdot 4B_2O_3$ - 431.92 - Colorless - M.P. 879 (L45) - R.I. ω 1.594, ε 1.559 (L45) - X-ray Lines 3.33, 2.90, 5.25 (L45)

Barium borate - $BaO \cdot 4B_2O_3$ (Glass) - 431.92 - Colorless - R.I. 1.558 (L45)

Barium borate - $2BaO \cdot B_2O_3$ - 376.36 - Colorless - M.P. 1002 (I8)

Barium borate - $3BaO \cdot B_2O_3$ - 529.72 - Colorless - M.P. 1383 (L45) - R.I. α 1.756, γ 1.768 (L45) - X-ray Lines 2.82, 3.24, 3.02 (L45)

Barium borate, fluo- - $BaF_2 \cdot 2BF_3$ - 311.00 - Colorless - D.T. 400 (R85)

Barium calcium aluminum silicate, hydrate - $BaO \cdot 2CaO \cdot 3Al_2O_3 \cdot 8SiO_2 \cdot 2H_2O$ (Nat. Armenite) - 1087.83 - Pseudo-hexagonal - D 2.76 (N20) - D.T. 450 (N20) - R.I. α 1.551, β 1.559, γ 1.562 (N20)

Barium calcium carbonate - $BaCO_3 \cdot CaCO_3$ (Nat. Barytocalcite) - 297.46 - Colorless - Monoclinic - D 3.65 (I8) - R.I. α 1.525, β 1.684, γ 1.686 (L18) - X-ray Lines 3.16, 3.96, 2.54 (A40)

Barium calcium silicate - $BaO \cdot 2CaO \cdot 3SiO_2$ - 445.70 - Colorless - Hexagonal - M.P. 1320 (Incong.) (I8) - R.I. ω 1.681, ε 1.668 (I8)

Barium carbide - BaC_2 - 161.38 - Gray - Tetragonal (B123)

Barium carbonate - $BaCO_3$ (I) - 197.37 - White - Regular -
(760 m.m.) (K14) - X-ray Lines 3.72, 2.63, 2.14 (Form
(A40)

Barium carbonate - $BaCO_3$ (II) - 197.37 - White - Hexagona
tion to I 982 (I8)

Barium carbonate - $BaCO_3$ (III) (Witherite) - 197.37 - Whi
- D 4.274 (B49) - Transition to II 811 (B82) - M.P. 17
CO_2) (K79) - D.T. 1352 (1 atm. CO_2) (K79) - R.I. α 1.5
γ 1.677 (I8) - X-ray Lines 3.58, 2.56, 1.91 (A41)

Barium carbonate, oxy- - $BaCO_3 \cdot BaO$ - 350.73 - D.T. 1491 (
(K14)

Barium cerate - $BaO \cdot CeO_2$ - 325.49 - Cubic - D 6.40 (X-ray
X-ray Lines 3.10, 1.794, 2.18 (A40)

Barium chlorate - $Ba(ClO_3)_2$ - 304.27 - Colorless - M.P. 4
X-ray Lines 3.58, 3.34, 2.19 (A40)

Barium chlorate, per- - $Ba(ClO_4)_2$ - 336.27 - Colorless -
M.P. 505 (K79)

Barium chloride - $BaCl_2$ (I) - 208.27 - Colorless - Cubic
(W59) - M.P. 960 (K15) - B.P. 1560 (I8) - X-ray Lines
2.45 (Form not defined) (A41)

Barium chloride - $BaCl_2$ (II) - 208.27 - Colorless - Monoc
3.889 (G30) - T.P. 925 (I8) - R.I. α 1.73024, β 1.7361
(W58)

Barium chloride fluoride - BaClF - 191.82 - Colorless - T
D 5.931 (I8) - M.P. 1008 (I8) - R.I. ω 1.640, ε 1.633

Barium chloride, oxy- - $BaCl_2 \cdot 2BaO$ - 514.99 - M.P. 995 (I
(N17)

Barium chromate - $BaO \cdot CrO_3$ - 253.37 - Yellow - Rhombic -
(I8) - X-ray Lines 2.16, 3.19, 3.54 (A40)

Barium chromite - $BaO \cdot 4Cr_2O_3$ - 761.44 - Black - Hexagonal
(M29)

Barium cyanide - $Ba(CN)_2$ - 189.40 - Colorless - X-ray Lin
2.94 (A40)

Barium fluoride - BaF_2 - 175.36 - Colorless - Cubic - D 4
- M.P. 1287 (K15) - B.P. 2260 (R71) - R.I. 1.474127 (M
Lines 2.20, 1.87, 1.43 (A41)

Barium formate - $Ba(HCO_2)_2$ - 227.40 - Colorless - Rhombic
(A36) - R.I. α 1.567, β 1.587, γ 1.627 (A36) - X-ray L
5.4, 2.10 (A40)

Barium hydroxide - See Barium oxide, hydrate

Barium iron (III) oxide - $BaO \cdot Fe_2O_3$ - 313.06 - Hexagonal
(A34)

Barium iron (II) silicate - $BaO \cdot FeO \cdot 4SiO_2$ (Gillespite) -
Pink - Tetragonal - D 3.33 (I8) - R.I. ω 1.621, ε 1.61

Barium magnesium fluoride - $BaF_2 \cdot 2MgF_2$ - 300.00 - Colorle
(N30) - M.P. 930 (Incong.) (N30) - R.I. 1.467 (N30)

Barium manganate - $BaO \cdot MnO_3$ - 256.29 - Green - Hexagonal,
D 4.85^{25} (M29) - X-ray Lines 3.50, 3.16, 2.15 (A40)

Barium manganite - $BaO \cdot MnO_2$ - 240.29 - D 5.85 (I8)

Barium molybdate - $BaO \cdot MoO_3$ - 297.31 - White - Tetragonal - D 4.65 (I8) - M.P. 1480 (L48) - X-ray Lines 3.36, 2.79, 2.10 (A41)

Barium nickel (IV) oxide - $BaO \cdot 2NiO_2$ - 334.74 - D 4.8 (I8)

Barium nitrate - $Ba(NO_3)_2$ - 261.38 - Colorless - Cubic - D 3.232^{25} (W60) - M.P. 595.5 (H18) - D.T. 664 (K79) - R.I. 1.5715 (W60) - X-ray Lines 2.44, 4.69, 2.34 (Form not defined) (A40)

Barium nitrite - $Ba(NO_2)_2$ - 229.38 - Slight Yellow - Hexagonal - D 3.234^{0} (B155) - M.P. 267 (B155) - T.P. 201, 231 (B155) - D.T. 270 (B155)

Barium oxalate - BaC_2O_4 - 225.38 - Colorless - D 2.658 (I8) - D.T. 400 (C4) - X-ray Lines 3.20, 3.80, 7.7 (A40)

Barium oxide - BaO - 153.36 - Colorless - Hexagonal or Cubic - D 5.72 (I8) - M.P. 1925 (K79) - B.P. 2200 (H47) - R.I. 2.08 (Mean) (M42) - X-ray Lines 3.20, 2.75, 1.95 (A40)

Barium oxide, per- - BaO_2 - 169.36 - White - Powder - D 5.43^{25} (B39) - D.T. 480 (760 m.m.) (T59) - X-ray Lines 3.37, 2.68, 2.11 (A40)

Barium oxide, hydrate - $BaO \cdot H_2O$ - 171.38 - Colorless - Rhombic - D 4.49 (I8) - M.P. 408 (S49) - D.T. 988 (760 m.m.) (I8) - X-ray Lines 3.39, 4.03, 2.46 (A40)

Barium oxide, hydrate - $BaO \cdot 2H_2O$ - 189.40 - Colorless - D 3.743 (N32) - X-ray Lines 4.70, 2.33, 3.00 (A40)

Barium oxide, hydrate - $BaO \cdot 9H_2O$ - 315.50 - Colorless - Monoclinic - D 2.164 (N32) - M.P. 77.9 (I8) - R.I. α 1.4710, β 1.5017, γ 1.5017 (I8) - X-ray Lines 6.0, 4.62, 2.78 (Form not defined) (A40)

Barium oxide, per-, hydrate - $BaO_2 \cdot 8H_2O$ - 313.49 - Colorless - Hexagonal - D 2.292 (N32) - -8 H_2O at 130 (S15)

Barium phosphate, meta- - $BaO \cdot P_2O_5$ - 295.32 - White - Crystal - M.P. Red Heat (G37)

Barium phosphate, pyro- - $2BaO \cdot P_2O_5$ - 448.68 - White - Rhombic, Prism - D 3.9 (C15)

Barium phosphate, ortho- - $3BaO \cdot P_2O_5$ - 602.04 - Colorless, Transparent - Cubic - D 4.1 (I8) - M.P. 1727 (W49) - X-ray Lines 3.08, 2.97, 2.13 (A40)

Barium phosphate, ortho- - $3BaO \cdot P_2O_5$ - 602.04 - Rhombohedral - D 5.23 (Z11)

Barium phosphate, chloro- - $3Ba_3(PO_4)_2 \cdot BaCl_2$ - 2014.39 - Colorless - Hexagonal - D 5.949 (I8) - M.P. 1584 (I8) - R.I. ω 1.701, ϵ 1.699 (I8)

Barium phosphate, fluo- - $3Ba_3(PO_4)_2 \cdot BaF_2$ - 1981.48 - Colorless - Hexagonal - M.P. 1670 (I8) - R.I. ω 1.669, ϵ 1.665 (I8)

Barium phosphate, hydrate - $2BaO \cdot P_2O_5 \cdot H_2O$ - 466.70 - Colorless - Rhombic - D 4.165^{15} (I8) - R.I. α 1.635, β -, γ 1.617 (G7) - X-ray Lines 3.58, 2.51, 4.45 (A40)

Barium praseodymium oxide - $BaO \cdot PrO_2$ - 326.28 - Cubic - D 6.52 (X-ray) (H82)

Barium selenate - $BaO \cdot SeO_3$ - 280.32 - White - Rhombic - D 4.61 (H44)

Barium selenide - BaSe - 216.32 - Cubic - D 5.04 (H44) - R.I. 2.268 (H1)

Barium silicate - $BaO \cdot SiO_2$ (I) - 213.42 - Colorless - Monoclinic - D 4.399^{4} (I8) - M.P. 1604 (I8) - R.I. α 1.65, β 1.66, γ 1.67 (A46) - X-ray Lines 3.41, 3.70, 2.09 (A46)

Barium silicate - $BaO\cdot SiO_2$ (II) - 213.42 - Colorless - Rhomb
T.P. 1300+ (W55)
Barium silicate - $BaO\cdot SiO_2$ (Glass) - 213.42 - Colorless - D
(S95) - R.I. 1.672 (Extrapolated) (M77)
Barium silicate - $BaO\cdot 2SiO_2$ - 273.48 - Colorless - Rhombic -
(I8) - M.P. 1418 (G64) - R.I. α 1.597, β 1.612, γ 1.621
X-ray Lines 4.00, 3.14, 2.27 (A46)
Barium silicate - $BaO\cdot 2SiO_2$ (Glass) - 273.48 - Colorless -
1.6085 (M77)
Barium silicate - $2BaO\cdot SiO_2$ - 366.78 - Colorless - Rhombic
5.2 (T42) - M.P. >1755 (I8) - R.I. α 1.810, β -, γ 1.830
X-ray Lines 3.04, 2.94, 3.44 (A46)
Barium silicate - $2BaO\cdot 3SiO_2$ - 486.90 - Colorless - D 3.93^{4}
M.P. 1450 (I8) - R.I. α 1.620, β 1.625, γ 1.645 (I8) - X-
3.75, 3.68, 2.78 (A46)
Barium silicate, fluo- - $BaSiF_6$ - 279.42 - Hexagonal (H72) -
4.279^{18} (I8) - D.T. 430 (693 m.m.) (H15) - X-ray Lines 3.
2.23 (A40)
Barium silicate, hydrate - $BaO\cdot SiO_2\cdot 6H_2O$ - 321.52 - Rhombic
(I8) - R.I. α 1.542, β 1.548, γ 1.548± (I8)
Barium sulfate - $BaSO_4$ (I) - 233.43 - White - Monoclinic -
(I8) - M.P. 1580 (K79) - D.T. 1510 (1 atm.) (K79) - R.I.
β 1.636, γ 1.647 (W42) - X-ray Lines 2.10, 3.44, 3.10 (F
defined) (A40)
Barium sulfate - $BaSO_4$ (II) - 233.43 - White - Rhombic - D
(X-ray) (S119) - Transition to I 1178 (K79)
Barium sulfide - BaS - 169.43 - Colorless Transparent - Cub
4.25^{18} (I8) - M.P. >1660 (W54) - R.I. 2.155 (H1) - X-ray
3.18, 2.25, 3.67 (A40)
Barium tellurate - $BaO\cdot TeO_3$ - 328.97 - White - D 4.48^{18} (I8
Barium telluride - BaTe - 264.97 - Cubic - D 5.51 (H1) - R.
(H1) - X-ray Lines 3.50, 2.48, 2.02 (A41)
Barium thorium (IV) oxide - $BaO\cdot ThO_2$ - 417.48 - Cubic - D 7.
(X-ray) (H82)
Barium titanate - $BaO\cdot TiO_2$ - 233.26 - Yellowish - Cubic - D
(M22) (S119) - T.P. ~ 120 (K9), 113 (K8) - R.I. 2.3 (K
Barium titanate - $BaO\cdot TiO_2$ - 233.26 - Amber - Hexagonal - D
(B154) - T.P. 1050 (B154) - R.I. ω 2.2, ε 2.31 (B154)
Barium titanate - $BaO\cdot TiO_2$ - 233.26 - Monoclinic (N4)
Barium titanate - $BaO\cdot TiO_2$ - 233.26 - Triclinic - D 6.00 (X-
(M22) - T.P. -183 (M22)
Barium titanate, fluo- - $BaF_2\cdot TiF_4$ - 299.26 - X-ray Lines 3.
2.00 (A40)
Barium titanium silicate - $BaO\cdot TiO_2\cdot 3SiO_2$ (Nat. Benitoeite)
- Hexagonal - D 3.7 (I8) - R.I. ω 1.757, ε 1.804 (I8)
Barium tungstate - $BaO\cdot WO_3$ - 385.28 - Colorless - Tetragona
(I8) - X-ray Lines 3.34, 2.08, 1.695 (A40)
Barium tungsten silicate, hydrate - $2BaO\cdot 12WO_3\cdot SiO_2\cdot 16H_2O$ -
Monoclinic - R.I. α -, β 1.816, γ - (I8) (L12)
Barium uranium (VI) oxide - $BaO\cdot UO_3$ - 439.43 - Golden Yello
bic - D 7.60 (X-ray) (S4) (S119)

Barium uranium (VI) phosphate, hydrate - $BaO\cdot 2UO_3\cdot P_2O_5\cdot 8H_2O$ (Uranocircite) - 1011.59 - Orthorhombic - D 13.53 (I8) - R.I. α 1.610, β (1.623), γ 1.623 (I8) (L12)

Barium vanadate - $2BaO\cdot V_2O_5$ - 488.62 - White, fluoresces in ultraviolet light - M.P. 863± (I8)

Barium yttrium silicate, boro- - $BaO\cdot 3Y_2O_3\cdot 3B_2O_3\cdot 3SiO_2$ (Nat. Cappelenite) - 1219.98 - Greenish Brown - Hexagonal - D 4.4 (W42a) - R.I. ω 1.76, ε - (W42a)

Barium zinc fluoride - $BaF_2\cdot ZnF_2$ - 278.74 - M.P. 788 (M78) - R.I. 1.544 (M78)

Barium zirconate - $BaO\cdot ZrO_2$ - 276.58 - Cubic - D 6.26 (X-ray) (H82) - M.P. 2650 (K79) - X-ray Lines 2.97, 1.709, 2.09 (A40)

Beryllium - Be - 9.02 - Grayish White - Hexagonal, Close-Packed - D 1.85^{20} (A20) - M.P. 1280 (A20) - B.P. 2770 (A20) - X-ray Lines 1.73, 1.97, 1.79 (A40)

Beryllium aluminate - $BeO\cdot Al_2O_3$ (Chrysoberyll) - 126.96 - Colorless - Rhombic - D 3.76 (I8) - M.P. 1890 (G19) - R.I. α 1.747, β 1.748, γ 1.756 (G19) - X-ray Lines 2.08, 1.61, 3.24 (A41)

Beryllium aluminate - $BeO\cdot 3Al_2O_3$ - 330.84 - Colorless - R.I. ω 1.735, ε 1.745 (F48) - X-ray Lines 2.10, 1.428, 1.86 (F70)

Beryllium aluminum silicate - $3BeO\cdot Al_2O_3\cdot 6SiO_2$ (Beryl) - 537.36 - Colorless, Transparent - Hexagonal - D 2.66 (I8) - M.P. 1420 (K79) - R.I. ω 1.580, ε 1.574 (G7) - X-ray Lines 7.90, 3.25, 2.87 (A41)

Beryllium aluminum silicate, hydrate - $2BeO\cdot Al_2O_3\cdot 2SiO_2\cdot H_2O$ (Nat. Euclase) - 290.12 - Monoclinic - D 3.1 (I8) - R.I. α 1.652, β 1.655, γ 1.671 (I8)

Beryllium aluminum silicate, hydrate - $3BeO\cdot Al_2O_3\cdot 6SiO_2\cdot \frac{1}{2}H_2O$ (Meclov Beryl) - 546.37 - D 2.707 (K88) - R.I. ω 1.581, ε 1.575 (K88)

Beryllium borate, hydrate - $4BeO\cdot B_2O_3\cdot H_2O$ (Nat. Hambergite) - 187.74 - Colorless - Rhombic - D 2.35 (I8) - R.I. α 1.560, β 1.591, γ 1.631 (I8)

Beryllium carbide - Be_2C - 30.05 - Yellow - Hexagonal - D 1.90^{15} (R12) - M.P. >2100 (R12)

Beryllium chloride - $BeCl_2$ - 79.93 - Colorless - Needle - D 1.904^{25} (M44) - M.P. 404 (S14) - T.P. 300 (S14) - B.P. 488 (R1)

Beryllium fluoride - BeF_2 - 47.02 - Colorless - M.P. 538 (R57)

Beryllium fluoride - BeF_2 (Glass) - 47.02 - Colorless - D 1.986^{25} (B69) - T.P. 425, 528 (N35) - R.I. 1.27475 (P48)

Beryllium fluoride, oxy- - $5BeF_2\cdot 2BeO$ - 285.14 - White - D 2.3 (I8)

Beryllium germanate - $2BeO\cdot GeO_2$ - 154.64 - Colorless - D 3.868 (S20)

Beryllium hydroxide - $Be(OH)_2$ (I, metastable) - 43.04 - White - D 1.920^{20} (F58)

Beryllium hydroxide - $Be(OH)_2$ (II, stable) - 43.04 - White - Rhombic - D 1.924^{20} (F58)

Beryllium iron (II) yttrium silicate - $2BeO\cdot FeO\cdot Y_2O_3\cdot 2SiO_2$ (Nat. Gadolinite) - 467.85 - Monoclinic - D 4.3 (I8) - R.I. α 1.78+, β 1.78+, γ 1.785+ (I8)

Beryllium lead fluoride - $BeF_2\cdot PbF_2$ - 292.23 - Colorless - Rhombic - D 6.135^{30} (R10)

Beryllium manganese silicate - $BeO\cdot MnO\cdot SiO_2$ (Nat. Trimerite) - 156.01 - Triclinic - D 3.474 (F26) - R.I. α 1.715, β 1.720, γ 1.725 (F26)

Beryllium nitrate, hydrate - $Be(NO_3)_2 \cdot 3H_2O$ - 187.08 - Yellow - M.P. 60 (I8) - $-3H_2O$ at 160 (T19)

Beryllium oxide - BeO - 25.02 - White - Hexagonal - D 3.004 M.P. 2520 (W19) - B.P. $\sim$4260 (E20) - R.I. ω 1.719, ε 1. X-ray Lines 2.06, 2.34, 2.19 (A40)

Beryllium oxide, per- - BeO_2 - 41.02 - D.T. 18 (760 m.m.) (

Beryllium phosphate - $BeO \cdot P_2O_5$ (Glass) - 166.98 - Colorless 1.5005 (S117)

Beryllium selenate, hydrate - $BeSeO_4 \cdot 4H_2O$ - 224.04 - Colorle Rhombic - D 2.03 (I8) - $-2H_2O$ at 103; $-4H_2O$ at 300 (S55) α 1.4664, β 1.5007, γ 1.5027 (I8)

Beryllium selenide - $BeSe$ - 87.98 - Regular - D 4.315 (X-ra

Beryllium silicate - $BeO \cdot SiO_2$ - 85.08 - Colorless - D 2.35 M.P. >1755 (I8)

Beryllium silicate - $2BeO \cdot SiO_2$ (Phenacite) - 110.10 - Color Triclinic - D 2.985 (S20) - M.P. >1750 (Incong.?) (K79) ω 1.654, ε 1.668 (M50)

Beryllium silicate, hydrate - $4BeO \cdot 2SiO_2 \cdot H_2O$ (Nat. Bertrand 238.22 - Rhombic - D 2.6 (I8) - R.I. α 1.591, β 1.605, γ (I8)

Beryllium sulfate - $BeSO_4$ - 105.09 - Colorless - Rhombic - (I8) - D.T. 790 (760 m.m.) (M9) - X-ray Lines 3.77, 2.34 (A40)

Beryllium sulfide - BeS - 41.09 - Regular - D 2.36 (Z1)

Beryllium telluride - $BeTe$ - 136.63 - Gray - Cubic - D 5.09 (Z3)

Beryllium titanate - $BeO \cdot TiO_2$ - 104.92 - M.P. 1730 (K79)

Beryllium titanate - $3BeO \cdot TiO_2$ - 154.96 - M.P. 1800 (K79)

Beryllium tungsten silicate, hydrate - $BeO \cdot W_{12}O_{37} \cdot SiO_2 \cdot 31H_2$ 3442.62 - Cubic - D 3.61 (X-ray) (S119)

Bismuth - Bi - 209.00 - White - Hexagonal - D 9.80^{20} (A20) 271.3 (A20) - T.P. 75 (K79) - B.P. 1420 (A20) - X-ray Li 1.44, 2.34 (A41)

Bismuth (III) arsenate - $Bi_2O_3 \cdot As_2O_5$ - 695.82 - Colorless - clinic - D 7.14 (I8)

Bismuth (III) arsenate - $Bi_2O_3 \cdot As_2O_5$ - 695.82 - Tetragonal (X-ray) (M66)

Bismuth (III) arsenate - $Bi_2O_3 \cdot As_2O_5$ (Nat. Rooseveltite) - D 6.86 (H51)

Bismuth (III) carbonate, oxy- - $Bi_2O_3 \cdot CO_2$ (Nat. Beyerite) - White - D 6.56 (F70) - R.I. ω 2.13, ε 1.99 (F70) - X-ray 2.851, 2.721, 1.755 (F70)

Bismuth (III) carbonate, oxy- - $Bi_2O_3 \cdot CO_2$ (Bismutite) - 510 White - Tetragonal - D 8.26 (X-ray) (S119) (L3) - X-ray 2.94, 1.75, 1.62 (A41)

Bismuth (II) chloride - $BiCl_2$ - 279.91 - Black - Needle (Ex questionable) - D 4.86 - M.P. 163 (K79) - D.T. 300 (K79)

Bismuth (III) chloride - $BiCl_3$ - 315.37 - Colorless - D 4. - M.P. 224 (K15) - B.P. 441 (K13)

Bismuth (III) chloride, oxy- - $BiOCl$ - 260.46 - Colorless - Tetragonal - D 7.72 (I8) - R.I. ω 2.15 ($\lambda = 6708$ A), ε - (B9) - X-ray Lines 3.45, 2.67, 7.4 (A40)

Bismuth chromate - $Bi_2O_3 \cdot CrO_3$ - 566.01 - X-ray Lines 3.20, 10.5, 2.58 (A40)

Bismuth (III) fluoride - BiF_3 - 266.00 - Colorless or Gray - Hexagonal - D 8.35 (H25) - M.P. 727 (W12) - R.I. ω ε >1.74 (W12) - X-ray Lines 2.07, 1.76, 1.34 (A41)

Bismuth (V) fluoride - BiF_5 - 304.00 - Rhombic - S.P. 550 (W12)

Bismuth (III) fluoride, oxy- - $BiFO$ - 244.00 - Colorless - D 7.5 (I8)

Bismuth (III) molybdate - $Bi_2O_3 \cdot MoO_3$ (Nat. Koechlinite) - 609.95 - Greenish Yellow - Rhombic - R.I. α 2.52, β 2.61, γ 2.67 (All for Li-Line) (L18)

Bismuth (III) molybdate - $Bi_2O_3 \cdot 3MoO_3$ - 897.85 - Ivory-Colored - Tetragonal - D 6.07 (Z26) - M.P. 643 (Z26)

Bismuth (III) nitrate, hydrate - $Bi(NO_3)_3 \cdot 5H_2O$ - 485.10 - Colorless - Triclinic - D 2.83 (I8) - D.T. 30 (I8)

Bismuth (III) nitrate, hydrate - $Bi(NO_3)_3 \cdot 6H_2O$ - 503.12 - D 2.76 (I8)

Bismuth oxalate - $Bi_2(C_2O_4)_3$ - 682.06 - X-ray Lines 6.4, 4.17, 2.40 (A40)

Bismuth oxide - BiO - 225.00 - Gray Black - D 7.16 (N21)

Bismuth (III) oxide - Bi_2O_3 (I) - 466.00 - Yellow - Tetragonal - D 9.04 (S34) - M.P. 820 (K79) - B.P. 1890 (K79) - R.I. 1.91 (G41) - X-ray Lines 3.23, 2.67, 1.95 (A41)

Bismuth (III) oxide - Bi_2O_3 (II) - 466.00 - Yellow Orange - Monoclinic - D 9.32 (S34) - Transition to I 710 (S34) - X-ray Lines 3.17, 2.71, 1.750 (A41)

Bismuth (III) oxide - Bi_2O_3 - 466.00 - Yellow - Cubic - D 9.22 (S34) - Transition to I 704 (I8) - X-ray Lines 3.17, 2.71, 1.75 (S34)

Bismuth (III) oxide - α-Bi_2O_3 (Sillenite) - 466.00 - Gray Black - Cubic - D 8.80 (X-ray) (F70) - T.P. 704 (F70) - R.I. >2.42 (F70) - X-ray Lines 3.216, 1.743, 2.730 (F70)

Bismuth (III) oxide - β-Bi_2O_3 (Low Temp.) (Nat. Bismite) - 466.00 - Monoclinic - D 8.64 (F70) - R.I. >2.42 (F70) - X-ray Lines 3.232, 2.676, 1.95 (F70)

Bismuth oxide, di- - BiO_2 - 241.00 - D 5.6 (I8)

Bismuth (V) oxide - Bi_2O_5 - 498.00 - Brown - D 5.10 (I8) - -O at 250 (G41)

Bismuth (III) oxide, hydrate - $Bi_2O_3 \cdot 3H_2O$ (Nat. Bismite) - 520.05 - Colorless - Rhombic - D 4.962^{18} (N21) - D.T. 415 (I8) - R.I. ω 2.01, ε 1.82 (I8) - X-ray Lines 2.96, 2.72, 1.61 (A40)

Bismuth (V) oxide, hydrate - $Bi_2O_5 \cdot H_2O$ - 516.02 - Yellowish White - D 5.75 (I8) - D.T. 120 (I8)

Bismuth (III) phosphate - $Bi_2O_3 \cdot P_2O_5$ - 607.96 - Colorless - Monoclinic - D 6.323^{18} (S24) - X-ray Lines 3.08, 2.87, 4.20 (A40)

Bismuth selenide - $BiSe$ - 287.96 - D 7.98 (X-ray) (P10) - M.P. 605 (K79) - T.P. 422 (G41) - X-ray Lines 2.08, 3.01, 2.23 (A41)

Bismuth (III) selenide - Bi_2Se_3 (Guanajuatite) - 654.88 - Silver White - Rhombic - D 6.82 (I8) - M.P. 690 (K79) - X-ray Lines 2.99, 2.22, 2.06 (A41)

Bismuth (III) silicate - $Bi_2O_3 \cdot SiO_2$ - 526.06 - Yellowish B
8.92^{20} (O14) - M.P. 770-890 (O14)
Bismuth (III) silicate - $Bi_2O_3 \cdot 2SiO_2$ - 586.12 - D 8.66^{20} (
873 (O14)
Bismuth (III) silicate - $Bi_2O_3 \cdot 3SiO_2$ - 646.18 - Yellowish
8.11^{20} (O14) - M.P. 847 (O14)
Bismuth (III) silicate - $Bi_2O_3 \cdot 8SiO_2$ - 946.48 - Gray - Rho
6.62 (O14) - M.P. 992 (O14)
Bismuth (III) silicate - $2Bi_2O_3 \cdot SiO_2$ - 992.06 - Yellowish
9.14^{20} (O14) - M.P. 820 (O14)
Bismuth (III) silicate - $2Bi_2O_3 \cdot 3SiO_2$ - 1112.18 - D 8.984^{2}
M.P. 860 (O14)
Bismuth (III) silicate - $2Bi_2O_3 \cdot 3SiO_2$ (Nat. Agricolite) -
Yellow - Monoclinic - D 6 (I8) - R.I. α -, β 1.99, γ -
Bismuth (III) silicate - $2Bi_2O_3 \cdot 3SiO_2$ (Nat. Eulytite) - 11
Yellow - Cubic - D 6.11 (I8) - R.I. 2.05 (I8) - X-ray L
2.74, 1.67 (A41)
Bismuth (III) silicate - $3Bi_2O_3 \cdot SiO_2$ - 1458.06 - Brownish
8.90^{20} (O14) - M.P. 822 (O14)
Bismuth (III) silicate - $3Bi_2O_3 \cdot 2SiO_2$ - 1518.12 - Brown -
8.39^{20} (O14) - M.P. 790 (O14)
Bismuth (III) silicate - $10Bi_2O_3 \cdot SiO_2$ - 4720.06 - D 9.14 (
8.32 (O14)
Bismuth (III) sulfate - $Bi_2(SO_4)_3$ - 706.20 - Colorless - Ne
5.08^{16} (B24) - D.T. 773 (1 atm.) (K79) - X-ray Lines 4.
5.2 (A40)
Bismuth sulfide - BiS - 241.07 - Gray - D 7.7 (I8) - M.P.
Bismuth (III) sulfide - Bi_2S_3 (Bismuthinite) - 514.20 - Br
Black - Rhombic - D 7.39 (I8) - M.P. 747 (K15) - X-ray
3.08, 1.94 (A41)
Bismuth sulfide telluride - Bi_4S_3Te (Grunlingite) - 1059.8
Lines 3.10, 2.13, 2.25 (A41)
Bismuth sulfide telluride - Bi_2STe_2 (Nat. Tetradymite) - 7
7.37 (W9)
Bismuth (III) tantalate, fluo- - $BiTa_2O_6F$ - 685.76 - X-ray
3.02, 1.20, 1.17 (A41)
Bismuth (III) telluride - Bi_2Te_3 (Tetradymite) - 800.83 -
Rhombohedral - D 7.81 (P28) - M.P. 585 (Syn.) (K79) - X
3.20, 2.16, 5.06 (A41)
Bismuth (III) tungstate - $Bi_2O_3 \cdot WO_3$ (Russellite) - 729.92 -
Lines 3.08, 1.64, 1.91 (A41)
Bismuth (III) tungstate - $Bi_2O_3 \cdot 3WO_3$ - 1161.76 - Greenish
Monoclinic - D 8.24^{8} (Z26) - M.P. 832 (Z26)
Bismuth (III) vanadate - $Bi_2O_3 \cdot V_2O_5$ (Nat. Pucherite) - 647
dish Brown - Rhombic - D 6.25^{26} (I8) - R.I. α 2.41, β 2
(All for Li-Line) (I8)

Boric Acid - See Boron oxide, hydrate
Boron - B - 10.82 - Monoclinic Plate and Needle (Large Pure
of B) (L27) - D 2.34 (99.2-99.7% pure B) (F42) - M.P. ∼
(A20) - B.P. 2550 (A20)
Boron arsenate - $B_2O_3 \cdot As_2O_5$ - 299.46 - Tetragonal - D 3.642
R.I. ω 1.681, ε 1.690 (S28)
Boron carbide - B_4C - 55.29 - Black - Rhombic (Z35) - D 2.
M.P. 2350 (R12) - B.P. >3500 (R12) - X-ray Lines 2.38,
(A40)

Boron chloride - BCl_3 - 117.19 - Colorless Gas - D 1.3493^{11} (B128) - M.P. -108 (K79) - S.P. 12.5 (K13) - B.P. 18 (K79) - R.I. $1.4195^{8.7}$ (G23)

Boron fluoride - BF_3 - 67.82 - Colorless Gas - D 1.68^{-128} (Liquid) (F25); 1.98^{-188} (Solid) (L36) - M.P. -128 (K15) - B.P. -100.9 (K13)

Boron fluoride, ammoniated - $BF_3 \cdot NH_3$ - 84.85 - Rhombic - D 1.864^{25} (L25) - M.P. 163 (L25) - R.I. α 1.335, β 1.34-1.35, γ 1.36 (L25)

Boron fluoride, hydrate - $B_2O_3 \cdot 4HF \cdot H_2O$ - 167.69 - Colorless Liquid - D 1.657^{25} (S84) - B.P. 159.1 (745 m.m.) (S84) - R.I. 1.3414^{20} (S84)

Boron oxide - BO - 26.82 - Brown and Transparent (Z46)

Boron oxide - B_2O_3 - 69.64 - Colorless - Rhombohedral - D 2.460 (K85) - M.P. 450 (K85) - B.P. 1860 (Calc.) (C52) - R.I. ω 1.648, ε 1.615 (K85)

Boron oxide - B_2O_3 (Glass) - 69.64 - Colorless - D 1.812 (M77) - R.I. 1.458 (M77)

Boron oxide, hydrate - $B_2O_3 \cdot H_2O$ (I) - 87.66 - Colorless - Rhombic - D 2.486 (K85) - M.P. 236 (K85) - R.I. 1.619 (K85) - X-ray Lines 4.20, 3.06, 2.19 (Form not defined) (A40)

Boron oxide, hydrate - $B_2O_3 \cdot H_2O$ (II) - 87.66 - Colorless - Monoclinic - D 2.044 (K85) - M.P. 200.9 (K85) - R.I. α 1.434, β 1.570, γ 1.588 (K85)

Boron oxide, hydrate - $B_2O_3 \cdot H_2O$ (III) - 87.66 - Colorless - Rhombic - D 1.78 (K85) - M.P. 176.0 (K85) - R.I. α <1.376, β 1.514, γ 1.521 (K85)

Boron oxide, hydrate - $B_2O_3 \cdot 3H_2O$ (Sassolite) - 123.69 - Colorless - Triclinic - D 1.49 (I8) - M.P. 170.9 (Incong.) (K85) - R.I. α 1.337, β 1.461, γ 1.462 (K85) - X-ray Lines 3.16, 5.9, 2.23 (Form not defined) (A40)

Boron phosphate - $B_2O_3 \cdot P_2O_5$ - 211.60 - Colorless - Tetragonal - D 2.802 (X-ray) (S26) - R.I. ω 1.595, ε 1.601 (S26) - X-ray Lines 3.62, 2.25, 1.865 (A40)

Boron silicon carbide - BSiC - 50.89 - Cubic - D 3.216 (T22) - R.I. 2.63 (Red) (T22)

Boron sulfide - B_2S_3 - 117.84 - Colorless - Vitreous or Needle - D 1.55 (G41) - M.P. 310 (G41)

Boron sulfuryl fluoride - $BF_3 \cdot SO_2F_2$ - 169.89 - M.P. -140.8 (B99)

Bromine - Br (Br_2) - 79.916 (A20) - Deep Red Liquid - Rhombic - D 3.12^{20} (A20) - M.P. -7.2 (A20) - B.P. 58.78 (A20)

Cadmium - Cd - 112.41 - Bluish White - Hexagonal - D 8.65^{20} (A20) - M.P. 320.9 (A19) (U2) (A20) - B.P. 765 (A20) - X-ray Lines 2.325, 2.790, 1.893 (A40)

Cadmium antimonate - $2CdO \cdot Sb_2O_5$ - 580.34 - Pale Yellow - Cubic - D 6.5 (X-ray) (B1) - X-ray Lines 1.53, 1.17, 1.04 (A41)

Cadmium arsenate - $2CdO \cdot As_2O_5$ - 486.64 - Yellowish White - Rhombic - D 5.474 (S23)

Cadmium borate - $CdO \cdot B_2O_3$ - 198.05 - M.P. 850 (K79)

Cadmium borate - $2CdO \cdot 3B_2O_3$ - 465.74 - M.P. ~ 860 (H10)

Cadmium carbonate - $CdCO_3$ - 172.42 - Triclinic - D 4.258 344 (760 m.m.) (K14) - X-ray Lines 2.94, 1.83, 3.78 (

Cadmium cerium (IV) oxide - $CdO \cdot CeO_2$ - 300.54 - Light Br (N4)

Cadmium chloride - $CdCl_2$ - 183.32 - Colorless - Cubic - (I8) - M.P. 568 (I8) - S.P. 962.9 (K13) - X-ray Lines 3.27 (A40)

Cadmium chromate - $CdO \cdot CrO_3$ - 228.42 - Rhombic - D 4.48 (S119) (B119)

Cadmium chromite - $CdO \cdot Cr_2O_3$ - 280.43 - Black - Cubic - - X-ray Lines 2.59, 1.66, 1.52 (A41)

Cadmium chromium sulfide - $CdS \cdot Cr_2S_3$ - 344.69 - Cubic - (X-ray) (P18)

Cadmium columbate - $CdO \cdot Cb_2O_5$ - 394.23 - D 5.93^{17} (M29)

Cadmium cyanide - $Cd(CN)_2$ - 164.45 - White - D 2.23 (S53 >200 (H12)

Cadmium fluoride - CdF_2 - 150.41 - White - Cubic - D 6.6 M.P. 1110 (K15) - B.P. 1748 (R71) - R.I. 1.56 (M78)

Cadmium formate - $Cd(HCO_2)_2$ - 202.45 - Colorless - Rhomb (A36) - R.I. α 1.588, β 1.607, γ 1.685 (A36)

Cadmium hydroxide - $Cd(OH)_2$ - 146.43 - Colorless - Trigo (H94) - $-H_2O$ at 180 (K79) - X-ray Lines 4.70, 2.55, 3

Cadmium indium oxide - $CdO \cdot In_2O_3$ - 405.93 - White - Tetr 7.30 (P16) - X-ray Lines 1.61, 2.81, 1.84 (A41)

Cadmium iron (III) oxide - $CdO \cdot Fe_2O_3$ - 288.11 - Cubic - - M.P. 1540 (A34) - R.I. 2.39 (Li-Line) (L12) - X-ray 3.065, 1.670 (A40)

Cadmium molybdate - $CdO \cdot MoO_3$ - 272.36 - Yellow - Plates (X-ray) (G41)

Cadmium nitrate - $Cd(NO_3)_2$ - 236.43 - M.P. 350 (I8) - D. atm.) (K79)

Cadmium nitrate, hydrate - $Cd(NO_3)_2 \cdot 4H_2O$ - 308.49 - Colo or Needle - D 2.455 (I8) - M.P. 59.4 (I8) - B.P. 132 Lines 5.0, 4.40, 3.65 (A40)

Cadmium oxalate - CdC_2O_4 - 200.43 - D 3.32^{18} (I8) - D.T. X-ray Lines 5.7, 3.70, 2.85 (A40)

Cadmium oxide, sub- - Cd_2O - 240.82 - Green - D 8.192 (I

Cadmium oxide - CdO - 128.41 - Brown - Cubic - D 8.15 (I 1559 (K13) - R.I. 2.49 (Li-Line) (L12) - X-ray Lines 2.71 (A41)

Cadmium phosphate, pyro- - $2CdO \cdot P_2O_5$ - 398.78 - White - - D 4.965 (S23)

Cadmium phosphate, ortho- - $3CdO \cdot P_2O_5$ - 527.19 - Colorle 1500 (I8) - X-ray Lines 4.21, 8.5, 4.68 (A40)

Cadmium phosphate chloride - $3Cd_3(PO_4)_2 \cdot CdCl_2$ - 1764.89 - X-ray Lines 2.84, 2.78, 2.69 (A41)

Cadmium phosphate, hydrate - $CdO \cdot P_2O_5 \cdot 4H_2O$ - 342.43 - Co Trigonal - D 2.742 (I8) - D.T. 100 (I8)

Cadmium phosphate, hydrate - $2CdO \cdot P_2O_5 \cdot 2H_2O$ - 434.81 - W 4.965 (I8) - M.P. 900 (?) (I8)

Cadmium phosphate, hydrate - $5CdO \cdot 2P_2O_5 \cdot 5H_2O$ - 1016.05 - Monoclinic - D 4.13 (I8) - D.T. 550 (I8)

Cadmium selenate, hydrate - $CdO \cdot SeO_3 \cdot 2H_2O$ - 291.40 - Rhombic - D 3.632 (I8) - $-2H_2O$ at 170 (K36)

Cadmium selenide - CdSe - 191.37 - Gold Yellow or Gray - Hexagonal - D 5.81 (I8) - M.P. 1350 (C25) - X-ray Lines 3.73, 2.15, 3.30 (A41)

Cadmium selenite - $CdO \cdot SeO_2$ - 239.37 - Yellowish White - Rhombic

Cadmium selenite - $CdO \cdot 2SeO_2$ - 350.33 - Yellow - Rhombic

Cadmium silicate - $CdO \cdot SiO_2$ - 188.47 - Colorless - Rhombic - D 4.93 (I8) - M.P. 1242 (I8) - R.I. ω ε >1.739 (J10) - X-ray Lines 2.94, 4.91, 2.50 (A41)

Cadmium silicate - $2CdO \cdot SiO_2$ - 316.88 - D 5.833 (B67) - M.P. 1252 (Incong.) (K79) - R.I. ω ε >1.739 (J10)

Cadmium sulfate - $CdSO_4$ - 208.48 - White - Rhombic - D 4.691^{24} (I8) - M.P. 1000 (I8) - X-ray Lines 3.57, 2.51, 4.93 (A40)

Cadmium sulfate, hydrate - $CdSO_4 \cdot H_2O$ - 226.50 - Monoclinic - D 3.786 (I8) - T.P. 74.5 (B34)

Cadmium sulfate, hydrate - $CdSO_4 \cdot 7H_2O$ - 334.59 - Colorless - Monoclinic - D 2.48 (I8) - T.P. 4 (I8)

Cadmium sulfate, hydrate - $3CdSO_4 \cdot 8H_2O$ - 769.57 - White - Monoclinic - D 3.09 (R12) - T.P. 41.5 (R12) - X-ray Lines 3.55, 4.90, 2.51 (A40)

Cadmium sulfide - β-CdS - 144.48 - Cubic - D 4.87 (X-ray) (S119) (F53)

Cadmium sulfide - CdS (Greenockite) - 144.48 - Yellow or Red - Hexagonal - D 4.820 (I8) - M.P. 1750 (100 atm.) (I8) - D.T. 1250 (13.02 m.m.) (P52) - Subl. begins at 980 (B44) - R.I. ω 2.506, ε 2.529 (I8) - X-ray Lines 3.15, 3.57, 2.06 (α form); 3.36, 2.06, 1.76 (β form) (A41)

Cadmium telluride - CdTe - 240.02 - Black - Cubic - D 6.20 (I8) - M.P. 1041 (I8)

Cadmium titanate - $CdO \cdot TiO_2$ (I) - 208.31 - Cubic

Cadmium titanate - $CdO \cdot TiO_2$ (II) - 208.31 - Rhombic - D 6.5 (X-ray) (Z7) - Transition to I 1050 (P59)

Cadmium tungstate - $CdO \cdot WO_3$ - 360.33 - Yellow - X-ray Lines 3.80, 3.05, 2.53 (A40)

Calcium - Ca - 40.08 - Yellowish White - Cubic - D 1.55 (A20) - M.P. 850 (A20) - T.P. 440 (K79) - B.P. 1440 (A20) - X-ray Lines 3.21, 2.80, 1.97 (A40)

Calcium aluminate - $CaO \cdot Al_2O_3$ - 158.02 - Colorless - Monoclinic, Rhombic, or Triclinic - D 2.981^{28} (S52) - M.P. 1600 (K79) - R.I. α 1.643, β 1.655, γ 1.663 (I8) - X-ray Lines 2.96, 2.52, 2.41 (A41)

Calcium aluminate - $CaO \cdot 2Al_2O_3$ - 259.96 - Colorless - Monoclinic - D 2.90 (L4) - M.P. 1765 (Incong.) (T9) - R.I. Identical with those for $3CaO \cdot 5Al_2O_3$ - X-ray Lines 3.51, 2.59, 1.53 (A41)

Calcium aluminate - $CaO \cdot 6Al_2O_3$ - 667.72 - Colorless - Hexagonal - D 3.38 (T45) - R.I. ω 1.702, ε 1.667 (T45)

Calcium aluminate - $3CaO \cdot Al_2O_3$ - 270.18 - Colorless - Cubic - D 3.00 (L4) - M.P. 1535 (Incong.) (K79) - R.I. 1.710 (I8) - X-ray Lines 2.70, 1.907, 1.556 (G63)

Calcium aluminate - $3CaO\cdot 5Al_2O_3$ (I) - 677.94 - A mixture o
$2Al_2O_3$ and $CaO\cdot Al_2O_3$ from X-ray study (Y2) - Colorless
M.P. 1720 (K79) - R.I. α 1.662, β 1.671, γ 1.674 (S52)
Lines 3.50, 2.59, 3.09 (Form not defined) (A41)

Calcium aluminate - $3CaO\cdot 5Al_2O_3$ (II) - 677.94 - Suggested
of Shepherd, Rankin and Wright was actually $CaO\cdot 2Al_2O_3$
Colorless - Tetragonal - R.I. ω 1.617, ε 1.651 (G47)

Calcium aluminate - $3CaO\cdot 16Al_2O_3$ - 1799.28 - Colorless - H
D 3.93 (X-ray) (L4) (S115)

Calcium aluminate - $5CaO\cdot 3Al_2O_3$ - 586.22 - Recently identi
$12CaO\cdot 7Al_2O_3$ (B147) (T31) - M.P. 1455 (K79) - X-ray Lin
5.04, 2.44 (A41)

Calcium aluminate - $5CaO\cdot 3Al_2O_3$ (Glass) - 586.22 - Colorle
1.662 (S52)

Calcium aluminate - $12CaO\cdot 7Al_2O_3$ (I) - 1386.54 - Yellow -
R.I. α 1.687, β -, γ 1.692 (R8)

Calcium aluminate - $12CaO\cdot 7Al_2O_3$ (II) - 1386.54 - Yellow -
2.69 (B147) - T.P. 1150-1200 (D43) - M.P. 1455 (I8) - R
(I8)

Calcium aluminate - $12CaO\cdot 7Al_2O_3$ (Glass) - 1386.54 - D >2.
R.I. >that of the corresponding crystal (B147)

Calcium aluminate, chloro-, hydrate - $3CaO\cdot Al_2O_3\cdot CaCl_2\cdot 10H$
561.33 - Colorless - X-ray Lines 7.86, 2.86, 3.86 (A41)

Calcium aluminate, fluo-, hydrate - $3CaF_2\cdot 2AlF_3\cdot 3H_2O$ - 456
White - D 2.77 (N24) - R.I. 1.413 (N24)

Calcium aluminate, hydrate - $3CaO\cdot Al_2O_3\cdot 6H_2O$ - 378.28 - Co
Cubic - D 2.522 (T30) - $-4H_2O$ at 275-450, $-6H_2O$ at 1000
R.I. 1.604 (T29) - X-ray Lines 2.28, 2.03, 5.13 (A41)

Calcium aluminate, hydrate - $3CaO\cdot Al_2O_3\cdot 8H_2O$ - 414.31 - Co
Hexagonal - D 2.130 (T30) - R.I. ω 1.538, ε 1.520 (T30)

Calcium aluminate, hydrate - $3CaO\cdot Al_2O_3\cdot 12H_2O$ - 486.37 - C
Hexagonal - R.I. ω 1.527, ε 1.503 (T30)

Calcium aluminate, hydrate - $4CaO\cdot Al_2O_3\cdot 12H_2O$ - 542.45 - C
R.I. ω 1.532, ε 1.505 (W32)

Calcium aluminate, hydrate - $4CaO\cdot Al_2O_3\cdot 13H_2O$ - 560.47 - C
R.I. ω 1.533, ε 1.522 (M94)

Calcium aluminate, hydrate - $6CaO\cdot Al_2O_3\cdot 33H_2O$ - 1032.95 -
Needle-like Prism - R.I. ω 1.475, ε 1.466 (F27)

Calcium aluminate, hydrate - $6CaO\cdot 2Al_2O_3\cdot 21H_2O$ - 918.69 - -
D 2.038 (T30) - R.I. ω 1.530, ε 1.510 (T30)

Calcium aluminate, hydrate - $8CaO\cdot 2Al_2O_3\cdot 27H_2O$ - 1138.95 -
- R.I. ω 1.535, ε 1.512 (A39)

Calcium aluminum manganese (III) silicate - $2CaO\cdot Al_2O_3\cdot Mn_2$
(Nat. Tinzenite) - 612.20 - Yellow - Monoclinic - D 3.2
R.I. α 1.693, β 1.701, γ 1.704 (L18)

Calcium aluminum phosphate, hydrate - $CaO\cdot 2Al_2O_3\cdot P_2O_5\cdot 5H_2$C
Crandallite) - 492.00 - Rhombic - D 3.5 (I8) - R.I. ω 1
1.585 (I8)

Calcium aluminum phosphate, hydrate - $2CaO\cdot 3Al_2O_3\cdot 2P_2O_5\cdot 7H$
Wavellite) - 828.01 - Colorless - X-ray Lines 2.92, 2.1
(A41)

Calcium aluminum phosphate, hydrate - $5CaO \cdot 6Al_2O_3 \cdot 4P_2O_5 \cdot 18H_2O$ (Nat. Pseudowavellite) - 1784.17 - Trigonal - D 2.9 (L18) - R.I. ω 1.622, ε 1.631 (L18)

Calcium aluminum phosphate, hydrate - $6CaO \cdot Al_2O_3 \cdot 2P_2O_5 \cdot 5H_2O$ (Nat. Dennisonite) - 812.42 - Colorless - Hexagonal - D 2.85 (L18) - R.I. ω 1.601, ε 1.591 (L18)

Calcium aluminum phosphate, hydrate - $8CaO \cdot 5Al_2O_3 \cdot 4P_2O_5 \cdot 14H_2O$ (Nat. Deltaite) - 1778.40 - Colorless - Trigonal - D 2.95 (L18) - R.I. ω 1.630, ε 1.640 (L18)

Calcium aluminum silicate - $CaO \cdot Al_2O_3 \cdot 2SiO_2$ (Anorthite) - 278.14 - Colorless - Triclinic - D 2.765 (I8) - M.P. 1553 (O10) - R.I. α 1.576, β 1.584, γ 1.588 (I8) - X-ray Lines 3.18, 2.51, 4.03 (A41)

Calcium aluminum silicate - $CaO \cdot Al_2O_3 \cdot 2SiO_2$ (Glass) - 278.14 - Colorless - D 2.700 (D11) - R.I. 1.5755 (L16)

Calcium aluminum silicate - $2CaO \cdot Al_2O_3 \cdot SiO_2$ (Gehlenite) - 274.16 - Colorless - Tetragonal - D 3.038 (F11) - M.P. 1590 (I8) - R.I. ω 1.669, ε 1.658 (I8) - X-ray Lines 2.81, 1.75, 1.38 (A41)

Calcium aluminum silicate - $2CaO \cdot Al_2O_3 \cdot SiO_2$ (Glass) - 274.16 - Colorless - D 2.884 (F11) - R.I. 1.638 (F11)

Calcium aluminum silicate - $2CaO \cdot 3Al_2O_3 \cdot 9SiO_2$ (Nat. Didymolite) - 958.52 - Monoclinic - D 2.71 (I8) - R.I. α -, β 1.501, γ - (I8)

Calcium aluminum silicate - $3CaO \cdot Al_2O_3 \cdot SiO_2$ - 330.24 - Colorless - Rhombic - M.P. 1335 (Incong.) (R8) - R.I. α 1.675, β -, γ 1.685 (I8)

Calcium aluminum silicate - $3CaO \cdot Al_2O_3 \cdot 3SiO_2$ (Nat. Grossularite) - 450.36 - Colorless - Cubic - D 3.530 (I8) - M.P. 1180 (Z34) - R.I. 1.735 (I8) - X-ray Lines 2.64, 1.58, 1.64 (A41)

Calcium aluminum silicate - $4CaO \cdot 3Al_2O_3 \cdot 6SiO_2$ (Nat. Meionite) - 890.50 - Tetragonal - D 2.74 (I8) - R.I. ω 1.597, ε 1.560 (I8)

Calcium aluminum silicate - $6CaO \cdot 4Al_2O_3 \cdot 9SiO_2$ (Mejonite) - 1284.78 - Tetragonal - R.I. ω 1.558-1.597, ε 1.543-1.561 (L9)

Calcium aluminum silicate - $6CaO \cdot 4Al_2O_3 \cdot 9SiO_2$ (Zoisite) - 1284.78 - Orthorhombic - R.I. α 1.700, β 1.700, γ 1.705 (L9)

Calcium aluminum silicate - $18CaO \cdot 4Al_2O_3 \cdot 15SiO_2$ (Idokras) - 2318.10 - R.I. ω 1.7205, ε 1.7235 (L9)

Calcium aluminum silicate, hydrate - $CaO \cdot Al_2O_3 \cdot 2SiO_2 \cdot 2H_2O$ (Nat. Hibschite) - 314.17 - Cubic - D 3.05 (I8) - R.I. 1.67 (I8)

Calcium aluminum silicate, hydrate - $CaO \cdot Al_2O_3 \cdot 2SiO_2 \cdot 2H_2O$ (Nat. Lawsonite) - 314.17 - Rhombic - D 3.09 (I8) - R.I. α 1.665, β 1.674, γ 1.684 (I8)

Calcium aluminum silicate, hydrate - $CaO \cdot Al_2O_3 \cdot 3SiO_2 \cdot 2H_2O$ (Nat. Scolecite) - 374.23 - Colorless - Monoclinic - D 2.274^{20} (H58) - R.I. α 1.513, β 1.520, γ 1.521 (H58)

Calcium aluminum silicate, hydrate - $CaO \cdot Al_2O_3 \cdot 3SiO_2 \cdot 5H_2O$ (Nat. Levynite) - 428.28 - Trigonal - D 2.1 (I8) - R.I. ω 1.496, ε 1.491 (I8)

Calcium aluminum silicate, hydrate - $CaO \cdot Al_2O_3 \cdot 4SiO_2 \cdot 4H_2O$ (Nat. Gismondite) - 470.32 - Colorless - Monoclinic - D 2.27 (L18) - R.I. α -, β 1.539, γ - (I8) - X-ray Lines 7.3, 3.24, 2.73 (A41)

Calcium aluminum silicate, hydrate - $CaO \cdot Al_2O_3 \cdot 4SiO_2 \cdot 4H_2O$ (Nat. Laumontite) - 470.32 - Monoclinic - D 2.3 (I8) - R.I. α 1.513, β 1.524, γ 1.525 (I8)

Calcium aluminum silicate, hydrate - $CaO \cdot Al_2O_3 \cdot 6SiO_2 \cdot 5H_2O$ (Nat. Epistilbite) - 608.46 - Monoclinic - D 2.25 (I8) - R.I. α 1.502, β 1.510, γ 1.512 (I8)

Calcium aluminum silicate, hydrate - $CaO \cdot Al_2O_3 \cdot 6SiO_2 \cdot 5H_2O$ (Nat. Heulandite) - 608.46 - Monoclinic - D 2.2 (I8) - R.I. α 1.498, β 1.499, γ 1.505 (I8)

Calcium aluminum silicate, hydrate - $CaO \cdot Al_2O_3 \cdot 7SiO_2 \cdot 7H_2O$ (Nat. Stellerite) - 704.55 - Rhombic - D 2.12 (I8) - R.I. α 1.484, β 1.492, γ 1.495 (I8)

Calcium aluminum silicate, hydrate - $CaO \cdot 2Al_2O_3 \cdot 2SiO_2 \cdot H_2O$ (Nat. Margarite) - 398.10 - Monoclinic - D 3.0 (I8) - R.I. α 1.632, β 1.643, γ 1.645 (I8)

Calcium aluminum silicate, hydrate - $2CaO \cdot Al_2O_3 \cdot 3SiO_2 \cdot H_2O$ - 412.30 - Rhombic - D 2.9 (I8) - R.I. α 1.616, β 1.626, γ 1.649 (I8) - X-ray Lines 3.49, 3.28, 3.05 (A41)

Calcium aluminum silicate, hydrate - $2CaO \cdot Al_2O_3 \cdot 5SiO_2 \cdot 6H_2O$ (Nat. Laubanite) - 622.50 - Monoclinic (?) - D 2.2 (I8) - R.I. ω 1.475, ϵ 1.486 (I8)

Calcium aluminum silicate, hydrate - $3CaO \cdot Al_2O_3 \cdot 2SiO_2 \cdot 2H_2O$ (Nat. Plazolite) - 426.33 - Cubic - D 3.55 (P3)

Calcium aluminum silicate, hydrate - $3CaO \cdot Al_2O_3 \cdot 6SiO_2 \cdot H_2O$ (Nat. Bavenite) - 648.55 - Monoclinic - D 2.72 (I8) - R.I. α 1.578, β 1.579, γ 1.583 (I8)

Calcium aluminum silicate, hydrate - $4CaO \cdot Al_2O_3 \cdot SiO_2 \cdot 12H_2O$ - 602.51 - Hexagonal Plate - R.I. ω 1.538, ϵ 1.523 (F27)

Calcium aluminum silicate, hydrate - $4CaO \cdot Al_2O_3 \cdot 4SiO_2 \cdot H_2O$ (Nat. Vesuvianite) - 584.51 - Tetragonal - D 3.36 (L18) - R.I. ω 1.719, ϵ 1.715 (L18)

Calcium aluminum silicate, hydrate - $4CaO \cdot 3Al_2O_3 \cdot 6SiO_2 \cdot H_2O$ (Nat. Clinozoisite) - 908.51 - Monoclinic - D 3.36 (I8) - R.I. α 1.724, β 1.729, γ 1.734 (I8)

Calcium aluminum silicate, hydrate - $4CaO \cdot 3Al_2O_3 \cdot 6SiO_2 \cdot H_2O$ (Nat. Zoisite) - 908.51 - Rhombic - D 3.3 (I8) - R.I. α 1.700, β 1.702, γ 1.706 (I8)

Calcium aluminum silicate, hydrate - $6CaO \cdot Al_2O_3 \cdot 3SiO_2 \cdot 30\text{-}32H_2O$ - Needle-shaped Prism - R.I. ω 1.487, ϵ 1.479 (F27)

Calcium aluminum silicate, hydrate - $6CaO \cdot 3Al_2O_3 \cdot 7SiO_2 \cdot 4H_2O$ (Nat. Pumpellyite) - 1134.78 - Monoclinic - D 3.2 (L18) - R.I. α 1.700, β 1.707, γ 1.718 (L18)

Calcium aluminum silicate, phospho-, hydrate - $5CaO \cdot 5Al_2O_3 \cdot 3P_2O_5 \cdot 3SiO_2 \cdot 25\text{-}30H_2O$ (Nat. Viseite) - Isotropic - D 2.2 (M31) - R.I. 1.530 (M31)

Calcium antimonate, pyro- - $2CaO \cdot Sb_2O_5$ - 435.68 - Yellow - Cubic - D 4.8 (X-ray) (B1) - X-ray Lines 1.55, 1.05, 1.82 (A41)

Calcium arsenate, ortho- - $3CaO \cdot As_2O_5$ - 398.06 - Colorless - D 3.620 (G82) - M.P. 1455 (G82) - X-ray Lines 2.90, 2.82, 3.51 (A40)

Calcium arsenate, hydrate - $2CaO \cdot As_2O_5 \cdot H_2O$ - 360.00 - Plates - R.I. α 1.625, β -, γ 1.655 (R12)

Calcium arsenate, hydrate - $2CaO \cdot As_2O_5 \cdot 3H_2O$ (Nat. Haidingerite) - 396.03 - Colorless - Rhombic - D 2.967 (I8) - R.I. α 1.590, β 1.602, γ 1.638 (I8)

Calcium arsenate, hydrate - $2CaO\cdot As_2O_5\cdot 5H_2O$ (Nat. Pharmacolite) - 432.06 - Colorless - Monoclinic - D 2.754 (L18) - R.I. α 1.583, β 1.589, γ 1.594 (I8)

Calcium arsenate, hydrate - $2CaO\cdot As_2O_5\cdot 8H_2O$ (Nat. Wapplerite) - 486.11 - Colorless - Triclinic - D 2.48 (I8) - R.I. α 1.525, β 1.537, γ 1.552 (I8)

Calcium arsenate, hydrate - $3CaO\cdot As_2O_5\cdot 2H_2O$ - 434.09 - Monoclinic - R.I. α -, β 1.615, γ 1.62 (R12)

Calcium arsenate, hydrate - $5CaO\cdot 2As_2O_5\cdot 6H_2O$ - 848.13 - R.I. α -, β 1.60, γ 1.64 (R12)

Calcium beryllium aluminum silicate, hydrate - $4CaO\cdot BeO\cdot Al_2O_3\cdot 9SiO_2\cdot H_2O$ (Nat. Bavenite) - 909.84 - Colorless - Rhombic - D 2.745 (K106) - R.I. α 1.583, β 1.585, γ 1.590 (K106)

Calcium beryllium fluoride - $CaF_2\cdot BeF_2$ - 125.10 - Colorless - Rhombic - D 2.959 (R10)

Calcium beryllium phosphate, hydrate - $2CaO\cdot 2BeO\cdot P_2O_5\cdot H_2O$ (Nat. Hydroherderite) - 322.26 - Colorless - Rhombic - D 3.00 (I8) - R.I. α 1.592, β 1.612, γ 1.621 (I8)

Calcium borate - $CaO\cdot B_2O_3$ - 125.72 - Colorless - Rhombic - D 2.71 (X-ray) (S119) - M.P. 1435 (K34) - R.I. α 1.550, β 1.660, γ 1.680 (C12)

Calcium borate - $CaO\cdot 2B_2O_3$ - 195.36 - Colorless - Rhombic - M.P. 1260 (K34) - R.I. ω 1.638, ε 1.568 (C12)

Calcium borate - $2CaO\cdot B_2O_3$ - 181.80 - Grains - M.P. 1585 (K34) - T.P. 531 (K34) - R.I. α 1.585, β 1.662, γ 1.667 (C12)

Calcium borate - $3CaO\cdot B_2O_3$ - 237.88 - Colorless - Prism - M.P. 1760 (K34) - R.I. ω 1.728, ε 1.630 (C12)

Calcium borate chloride, hydrate - $6CaO\cdot 9B_2O_3\cdot 2CaCl_2\cdot 4H_2O$ (Hilgardit) - 1257.28 - D 2.71 (H99) - R.I. α 1.630, β 1.636, γ 1.664 (H99)

Calcium borate, fluo- - $CaF_2\cdot 2BF_3$ - 213.72 - Rhombic - R.I. α -, β -, γ <1.26 (D19)

Calcium borate, hydrate - $CaO\cdot B_2O_3\cdot 6H_2O$ - 233.82 - Colorless - Tetragonal - D 1.88 (P29) - R.I. ω 1.520, ε 1.502 (M34)

Calcium borate, hydrate - $CaO\cdot 2B_2O_3\cdot 4H_2O$ (Nat. Bechilite) - 267.42 - R.I. ω 1.531, ε 1.510, α 1.477, β 1.488, γ 1.542 (L12)

Calcium borate, hydrate - $CaO\cdot 3B_2O_3\cdot 4H_2O$ - 337.06 - R.I. α 1.505, β -, γ 1.550 (N28)

Calcium borate, hydrate - $2CaO\cdot 3B_2O_3\cdot 2H_2O$ (Nat. Veatchite) - 357.11 - Colorless - Monoclinic - D 2.69 (S121) - R.I. α 1.551, β 1.553, γ 1.621 (S121)

Calcium borate, hydrate - $2CaO\cdot 3B_2O_3\cdot 5H_2O$ (Nat. Colemanite) - 411.16 - Colorless - Monoclinic - D 2.43 (I8) - R.I. α 1.586, β 1.592, γ 1.614 (I8)

Calcium borate, hydrate - $2CaO\cdot 3B_2O_3\cdot 7H_2O$ (Nat. Meyerhofferite) - 447.19 - Colorless - Trigonal - D 2.12 (I8) - R.I. α 1.500, β 1.535, γ 1.560 (I8)

Calcium borate, hydrate - $2CaO\cdot 3B_2O_3\cdot 9H_2O$ - 483.22 - Colorless - R.I. α 1.505, β -, γ 1.523 (M34)

Calcium borate, hydrate - $2CaO\cdot 3B_2O_3\cdot 13H_2O$ (Nat. Inyorite) - 555.28 - Colorless - Monoclinic - D 1.875 (I8) - R.I. α 1.492, β 1.505, γ 1.516 (B90) - X-ray Lines 2.79, 2.52, 3.03 (A41)

Calcium borate, hydrate - $2CaO \cdot 7B_2O_3 \cdot 8H_2O$ (Nat. Ginorite) - 743.77 - Monoclinic - R.I. α 1.517, β 1.524, γ 1.577 (D1)

Calcium borate, hydrate - $5CaO \cdot 6B_2O_3 \cdot 9H_2O$ (Nat. Priceite) - 860.38 - Colorless - Triclinic - D 2.4 (I8) - R.I. α 1.572, β 1.591, γ 1.594 (I8) - X-ray Lines 3.64, 2.18, 1.94 (A41)

Calcium borate, hydrate - $8CaO \cdot 10B_2O_3 \cdot 15H_2O$ (Nat. Pandermite) - 1415.28 - Colorless - Triclinic - D 2.43 (I8) - R.I. α 1.582, β 1.592, γ <1.606 (I8)

Calcium carbide - CaC_2 - 64.10 - Greenish Yellow - Rhombic - D 2.22 (I8) - M.P. 2300 (I8) - R.I. α >1.75, β -, γ - (W8) - X-ray Lines 2.93, 2.79, 1.95 (β Form); 2.86, 2.92, 2.05 (γ Form) (A40)

Calcium carbide - α-CaC_2 - 64.10 - Cubic - T.P. Room Temperature, 450 (B123) - X-ray Lines 2.74, 3.78, 2.08 (A40)

Calcium carbide, oxy- - $CaO \cdot CaC_2$ - 120.18 - M.P. 1980 (F32)

Calcium carbonate - $CaCO_3$ - 100.09 - Colorless - D $2.71031^{20°}$ (H102) - M.P. 1282 (Under its own equilibrium pressure) (K15) - D.T. 894.4 (760 m.m.) (S83) - X-ray Lines 3.03, 1.92, 1.87 (A41)

Calcium carbonate - $CaCO_3$ (Aragonite) - 100.09 - Colorless - Rhombic - D 2.930 (A25) - Transition to Calcite 520 (Z41) - R.I. α 1.5299, β 1.6809, γ 1.6854 (I8) - X-ray Lines 3.40, 1.98, 2.70 (A40)

Calcium carbonate - $CaCO_3$ (Calcite) - 100.09 - Colorless - Rhombic, Hexagonal - D $2.71030 \pm 0.00003^{20°}$ (D38) - M.P. 1339 (1025 atm.) (I8) - T.P. 970 (Under CO_2 pressure) (B81) - D.T. 898.6 (I8) - R.I. ω 1.6583, ε 1.4864 (I8) - X-ray Lines 3.02, 1.92, 1.87 (A41)

Calcium carbonate - $CaCO_3$ (Vaterite) - See Calcite or $\mu CaCO_3$ (See Gibson, Wyckoff and Merwin (G26) - Transition to Calcite 430-440 (K79) - X-ray Lines 2.73, 3.29, 3.58 (A40); 4.28, 2.71, 2.06 (A41)

Calcium carbonate - μ-$CaCO_3$ - 100.09 - Colorless - Hexagonal - D 2.54 (J29) - R.I. ω 1.550, ε 1.650 (J29)

Calcium carbonate, bi- - $Ca(HCO_3)_2$ - 162.12 - Colorless - Rhombic - D 2.015 (I8) - R.I. α 1.5101, β 1.5135, γ 1.5775 (I8)

Calcium carbonate, hydrate - $CaCO_3 \cdot H_2O$ - 118.11 - Colorless - D 1.992 (K94)

Calcium carbonate, hydrate - $CaCO_3 \cdot 5H_2O$ - 190.17 - Colorless - D 1.830 (H98)

Calcium carbonate, hydrate - $CaCO_3 \cdot 6H_2O$ - 208.19 - Colorless - Monoclinic - D $1.771^{0°}$ (K94) - R.I. α 1.460, β 1.535, γ 1.545 (I8)

Calcium carbonate phosphate - $CaCO_3 \cdot 2Ca_3(PO_4)_2$ (Nat. Dahllite) - 720.49 - Colorless - Hexagonal - D 3.08 (I8) - D.T. 1470 (E10) - R.I. ω 1.635, ε 1.631 (I8)

Calcium carbonate phosphate - $CaCO_3 \cdot 3Ca_3(PO_4)_2$ (Podolite) - 1030.69 - Colorless - Hexagonal - D 3.08 (I8) - M.P. 1470 (Incong.) (110 atm. CO_2) (K79) - R.I. ω 1.635, ε 1.626 (E11)

Calcium carbonate silicate sulfate, hydrate - $3CaO \cdot CO_2 \cdot SiO_2 \cdot SO_3 \cdot 14H_2O$ (Nat. Thaumasite) - 442.60 - Hexagonal - D 1.87 (I8) - R.I. ω 1.505, ε 1.468 (L12)

Calcium cerium (IV) oxide - $CaO \cdot CeO_2$ - 228.21 - White - D 3.32 (N4)

Calcium chloride - $CaCl_2$ (Hydrophilite) - 110.99 - Colorless - Rhombic and Pseudo-tetragonal - D 2.1741 (G30) - M.P. 782 (K15) - B.P. >1600 (I8) - R.I. α 1.600, β 1.605, γ 1.613 (S65) - X-ray Lines 4.49, 3.05, 2.33 (A40); 3.03, 2.32, 1.90 (A41)

Calcium chloride fluoride - $CaClF$ - 94.54 - Colorless - D 3.07 (I8) - D.T. 737 (I8) - X-ray Lines 2.56, 2.75, 1.94 (A40)

Calcium chloride, hydrate - $CaCl_2 \cdot 4H_2O$ - 183.05 - Colorless - D 1.826 (W61) - R.I. α 1.548, β -, γ 1.566 (W61) - X-ray Lines 2.63, 2.22, 4.70 (A40)

Calcium chloride, hydrate - $CaCl_2 \cdot 6H_2O$ - 219.09 - Colorless - Hexagonal - D 1.71.21 (W61) - M.P. 29.9 (K79) - R.I. ω 1.5504, ε 1.4949 (W61) - X-ray Lines 2.16, 3.93, 2.78 (A40); 3.91, 3.40, 2.57 (A41)

Calcium chloride, oxy- - $CaO \cdot 4CaCl_2$ - 500.04 - M.P. 839 (N17) - T.P. 700 (N17)

Calcium chromate - $CaO \cdot CrO_3$ - 156.09 - Tetragonal - D 3.22 (X-ray) (C41) - D.T. 1125 (A43) - X-ray Lines 3.63, 2.70, 1.86 (A40)

Calcium chromate, di- - $CaO \cdot 2CrO_3$ - 256.10 - X-ray Lines 3.90, 3.50, 7.0 (A40)

Calcium chromate - $3CaO \cdot 2CrO_3$ - 368.26 - R.I. α 1.980, γ 2.082 (V5)

Calcium chromite - $CaO \cdot Cr_2O_3$ - 208.10 - Green, Dark Green (V6) - Rhombic - D 4.8 (I8) - M.P. 2170 (W19) - R.I. α 2.18±0.02, γ 2.33±0.02 (V6)

Calcium chromite - $2CaO \cdot Cr_2O_3$ - 264.18 - Green - R.I. α 2.20, β -, γ 2.29 (V2)

Calcium chromite - $3CaO \cdot Cr_2O_3$ - 320.26 - R.I. ω 1.950, ε 1.923 (V3)

Calcium chromium (III) silicate - $3CaO \cdot Cr_2O_3 \cdot 3SiO_2$ (Nat. Uvarovite) - 500.44 - Green - Cubic - D 3.42 (I8) - R.I. 1.838 (I8)

Calcium columbate - $2CaO \cdot Cb_2O_5$ - 377.98 - Colorless - Prismatic - D 4.48 (M29)

Calcium columbium tantalate, fluo- - $6CaO \cdot CbOF_3 \cdot 3Ta_2O_5$ (Microlith) - 1827.67 - Cubic - R.I. 1.930 (L11)

Calcium copper (II) silicate - $CaO \cdot CuO \cdot 4SiO_2$ (Egyptian Blue) - 375.86 - Blue - Tetragonal - D 2.95 (L31) - R.I. ω 1.635, ε 1.605 (L31)

Calcium fluoride - CaF_2 (Nat. Fluorite) - 78.08 - Colorless - Cubic - D 3.180 (I8) - M.P. 1386 (E12) - B.P. 2500 (R71) - R.I. 1.433840 (S11) - X-ray Lines 1.93, 3.15, 1.64 (A41)

Calcium formate - $Ca(HCO_2)_2$ - 130.12 - Colorless - Rhombic - D 2.014 (A36) - R.I. α 1.510, β 1.514, γ 1.574 (A36) - X-ray Lines 5.6, 3.43, 2.99 (A40)

Calcium germanate - $2CaO \cdot GeO_2$ - 216.76 - White - Triclinic - R.I. α 1.724, γ 1.734 (Z39)

Calcium hydroxide - $Ca(OH)_2$ - 74.10 - Colorless - Hexagonal - D 2.230 (A37) - D.T. 545 (K79) - $-H_2O$ at 525 (G29) - R.I. ω 1.574, ε 1.545 (A37) - X-ray Lines 2.62, 4.91, 1.92 (A41)

Calcium indium oxide - $CaO \cdot In_2O_3$ - 333.60 - Colorless - Tetragonal - D 5.87 (X-ray) (P16) - X-ray Lines 1.61, 1.97, 1.39 (A41)

Calcium iron (III) aluminate - $4CaO \cdot Fe_2O_3 \cdot Al_2O_3$ - 485.88 - Brown - Rhombic - D 3.77 (H14) - M.P. 1418 (T16) - R.I. α 1.98, β 2.05, γ 2.08 (All for λ = 5 780 A) (H14) - X-ray Lines 2.63, 1.92, 2.77 (A41)

Calcium iron (II) carbonate - $CaFe(CO_3)_2$ (Nat. Ferrodolomite) - 215.95 - Trigonal - R.I. ω 1.741, ε 1.536 (F41)

Calcium iron (II) oxide - $CaO \cdot 9FeO$ - 702.73 - M.P. 1310 (M12)

Calcium iron (III) oxide - $CaO \cdot Fe_2O_3$ - 215.78 - Reddish Brown - Trigonal Tetragonal - D 5.08 (N2) - M.P. 1216 (Incong.) (I8) - R.I. ω 2.58, ε 2.43 (I8)

Calcium iron (III) oxide - $2CaO \cdot Fe_2O_3$ - 271.86 - Light Brown - Tabular - D 3.98 (N2) - M.P. 1436 (Incong.) (I8) - R.I. α 2.200, β 2.200, γ 2.290 (All for Li-Line) (I8) - X-ray Lines 2.67, 1.94, 2.79 (A41)

Calcium iron (III) oxide - $3CaO \cdot Fe_2O_3$ - 327.94 - Deep Ruby Red - Monoclinic - R.I. α -, β >1.73, γ - (F14)

Calcium iron (III) oxide - $4CaO \cdot 3Fe_3O_4$ - 918.97 - Needle - M.P. 1200 (M12)

Calcium iron (III) oxide, hydrate - $3CaO \cdot Fe_2O_3 \cdot 6H_2O$ - 436.04 - Cubic - D 2.77 (E5) - D.T. 210 (F29) - R.I. 1.710 (E5)

Calcium iron (III) oxide, hydrate - $3CaO \cdot Fe_2O_3 \cdot 6H_2O$ - 436.04 - Hexagonal - R.I. 1.61-1.66 (E5)

Calcium iron (II) phosphate, hydrate - $2CaO \cdot FeO \cdot P_2O_5 \cdot 4H_2O$ (Nat. Anapaite) - 398.03 - Triclinic - D 2.82 (I8) - R.I. α 1.602, β 1.613, γ 1.649 (I8)

Calcium iron (III) phosphate, hydrate - $6CaO \cdot 3Fe_2O_3 \cdot 4P_2O_5 \cdot 19H_2O$ (Nat. Calcioferrite) - 1725.72 - Monoclinic - D 2.53 (I8) - R.I. ω 1.575, ε 1.57 (I8)

Calcium iron (II) silicate - $CaO \cdot FeO \cdot SiO_2$ - 187.99 - Rhombic - M.P. 1208 (B115) - R.I. α 1.6958, β 1.7340, γ 1.7430 (H85)

Calcium iron (II) silicate - $CaO \cdot FeO \cdot 2SiO_2$ (Hendenbergite) - 248.05 - Monoclinic - D 3.53 (P51) - M.P. 1100 (I8) - T.P. 965 (B116) - R.I. α 1.726, β 1.735, γ 1.752 (W44)

Calcium iron (II) silicate - $2CaO \cdot FeO \cdot 2SiO_2$ (Nat. Ferroakermanite) - 304.13 - R.I. ω 1.670, ε 1.658 (H85)

Calcium iron (III) silicate - $3CaO \cdot Fe_2O_3 \cdot 3SiO_2$ - 508.12 - Cubic - D 3.793 (M38) - M.P. about 1100 (G41) - R.I. 1.9 (L11)

Calcium lanthanum silicate - $CaO \cdot La_2O_3 \cdot 2SiO_2$ - 502.04 - Colorless - Hexagonal - R.I. ω 1.880, ε 1.874 (E14)

Calcium lead silicate - $2CaO \cdot PbO \cdot 3SiO_2$ - 515.55 - D 3.99 (I8) - R.I. α -, β 1.795, γ - (I8)

Calcium lead silicate, hydrate - $4CaO \cdot 6PbO \cdot 6SiO_2 \cdot H_2O$ (Nat. Ganomalite) - 1941.96 - Tetragonal - D 5.74 (I8) - R.I. ω 1.910, ε 1.945 (I8)

Calcium magnesium aluminum silicate - $CaO \cdot MgO \cdot Al_2O_3 \cdot SiO_2$ (Nat. Gehlenite) - 258.40 - Tetragonal - D 3.04 (I8) - R.I. ω 1.666, ε 1.661 (I8)

Calcium magnesium aluminum silicate, hydrate - $10CaO \cdot 4MgO \cdot Al_2O_3 \cdot 11SiO_2 \cdot 4H_2O$ (Nat. Juanite) - 1556.74 - Rhombic - R.I. α 1.640, β -, γ 1.647 (L12)

Calcium magnesium borate, hydrate - $CaO \cdot MgO \cdot 3B_2O_3 \cdot 6H_2O$ (Nat. Hydroboracite) - 413.42 - Colorless - Monoclinic Needle - D 2.0 (I8) - R.I. α 1.517, β 1.534, γ 1.565 (I8) - X-ray Lines 2.44, 1.91, 2.21 (A41)

Calcium magnesium borate, hydrate - $CaO \cdot MgO \cdot 3B_2O_3 \cdot 11H_2O$ (Nat. Inderborite) - 503.50 - Colorless - Monoclinic (G55) - D 1.93 (G55) - R.I. α 1.480, β 1.509, γ 1.527 (K107)

Calcium magnesium carbonate - $CaMg(CO_3)_2$ (Nat. Dolomite) - 184.42 - Colorless - Trigonal - D 2.872 (I8) - D.T. (1 atm. CO_2) <500, 890 (K79) - R.I. ω 1.6817, ε 1.5026 (I8) - X-ray Lines 2.88, 1.80, 2.19 (A41)

Calcium magnesium fluoride - $CaF_2 \cdot 2MgF_2$ (Nat. Zamboninite) - 202.72 - Rhombic (?) - R.I. α 1.405, β -, γ 1.411 (S94)

Calcium magnesium iron (III) aluminate - $4CaO\cdot 2MgO\cdot Fe_2O_3\cdot Al_2O_3$ - 566.60 - Brown - D 3.72 (H13) - M.P. 1370 (Incong.) (H13) - T.P. 1300 (H13) - R.I. α 1.92, β -, γ 1.97 (All for Li-Line) (H13) - X-ray Lines 2.65, 2.78, 2.05 (A41)

Calcium magnesium iron (III) oxide - $2CaO\cdot MgO\cdot Fe_2O_3$ - 312.18 - Brown - M.P. 1410 (Incong.) (H13) - R.I. α 2.13, β -, γ 2.28 (All for Li-Line) (H13) - X-ray Lines 2.67, 1.93, 2.78 (A41)

Calcium magnesium silicate - $CaO\cdot MgO\cdot SiO_2$ (Monticellite) - 156.46 - Colorless - Rhombic - D 3.2 (I8) - M.P. 1580 (Incong.) (K79) - R.I. α 1.639, β 1.646, γ 1.653 (F13) - X-ray Lines 1.801, 1.583, 2.65 (C30)

Calcium magnesium silicate - $CaO\cdot MgO\cdot 2SiO_2$ (Diopside) - 216.52 - Colorless - Monoclinic - D 3.275 (A11) - M.P. 1392 (S6) - R.I. α 1.665, β 1.672, γ 1.695 (S6) - X-ray Lines 2.52, 2.99, 1.617 (C30)

Calcium magnesium silicate - $CaO\cdot 3MgO\cdot 4SiO_2$ (Nat. Tremolite) - 417.28 - Monoclinic - D 3.0 (I8) - R.I. α 1.609, β 1.623, γ 1.635 (I8) - X-ray Lines 3.36, 1.52, 4.61 (A41)

Calcium magnesium silicate - $2CaO\cdot MgO\cdot 2SiO_2$ (Akermanite) - 272.60 - Tetragonal - D 2.944 (I8) - M.P. 1458 (I8) - R.I. ω 1.633, ε 1.639 (I8) - X-ray Lines 2.86, 1.752, 2.02 (C30)

Calcium magnesium silicate - $2CaO\cdot MgO\cdot 2SiO_2$ (Glass) - 272.60 - Colorless - D 2.955 (F11) - R.I. 1.641 (F11)

Calcium magnesium silicate - $3CaO\cdot MgO\cdot 2SiO_2$ (Nat. Merwinite) - 328.68 - Colorless - Monoclinic - D 3.15 (I8) - M.P. 1575 (Incong.) (O11) - R.I. α 1.708, β 1.711, γ 1.718 (I8) - X-ray Lines 1.899, 2.67, 1.525 (C30)

Calcium magnesium silicate - $5CaO\cdot 2MgO\cdot 6Si9_2$ - 721.40 - Rhombic - M.P. 1365 (Incong.) (I8) - R.I. α 1.621, β 1.627, γ 1.635 (I8)

Calcium manganese carbonate - $CaMn(CO_3)_2$ (Nat. Mangandolomite) - 215.03 - Trigonal - R.I. ω 1.741, ε 1.536 (F41)

Calcium manganese (II) phosphate, hydrate - $2CaO\cdot MnO\cdot P_2O_5\cdot 2H_2O$ (Nat. Fairfieldite) - 361.08 - Triclinic - D 3.07 (I8) - R.I. α 1.636, β 1.644, γ 1.654 (L9)

Calcium manganese silicate - $CaO\cdot MnO\cdot SiO_2$ (Glaucochroite) - 187.07 - Pale Pink - Rhombic - D 3.39 (T39) - M.P. 1230 (in N_2) (T39) - R.I. α 1.679, β 1.716, γ 1.729 (L18)

Calcium manganese silicate - $CaO\cdot MnO\cdot 2SiO_2$ (Nat. Schaller) - 247.13 - Monoclinic - D 3.6 (S10) - R.I. α 1.710, β 1.719, γ 1.738 (S10)

Calcium manganese silicate - $CaO\cdot MnO\cdot 2SiO_2$ (Nat. Bustamite) - 247.13 - Pale Pink - Triclinic - D 3.32 (L18) - R.I. α 1.672, β 1.685, γ 1.687 (L18)

Calcium manganese (III) silicate, hydrate - $4CaO\cdot 2Mn_2O_3\cdot 5SiO_2\cdot 4H_2O$ (Nat. Orientite) - 912.40 - Rhombic - D 3.1 (I8) - R.I. α 1.758, β 1.776, γ 1.795 (I8)

Calcium molybdate - $CaO\cdot MoO_3$ - 200.03 - Colorless - Tetragonal - D 4.35 (I8) - R.I. ω 1.967, ε 1.978 (I8)

Calcium molybdate - $3CaO\cdot 10MoO_3$ - 1607.74 - White - M.P. ~ 500 (C16)

Calcium neodymium silicate - $CaO\cdot Nd_2O_3\cdot 2SiO_2$ - 512.74 - Colorless - Hexagonal - R.I. ω 1.903, ε 1.898 (E14)

Calcium nitrate - $Ca(NO_3)_2$ - 164.10 - Colorless - Cubic - D 2.36 (I8) - M.P. 561 (I8) - R.I. 1.595 (W42)

Calcium nitrate, hydrate - $Ca(NO_3)_2\cdot 3H_2O$ - 218.14 - M.P. 51.1 (I8)

Calcium nitrate, hydrate - $Ca(NO_3)_2 \cdot 4H_2O$ (I) - 236.16 - Colorless - Monoclinic - D 1.82 (I8) - M.P. 42.7 (I8) - R.I. α 1.465, β 1.498, γ 1.504 (I8)

Calcium nitrate, hydrate - $Ca(NO_3)_2 \cdot 4H_2O$ (II) - 236.16 - Colorless - M.P. 39.7 (I8)

Calcium nitrite - $Ca(NO_2)_2$ - 132.10 - D 2.265 (B155) - T.P. 138 (B155) - D.T. 250 (B155) - X-ray Lines 2.19, 2.29, 4.39 (A40)

Calcium oxalate - CaC_2O_4 - 128.10 - Colorless - Cubic - D 2.2 (I8) - X-ray Lines 5.9, 3.65, 2.98 (A40)

Calcium oxalate, hydrate - $CaC_2O_4 \cdot H_2O$ (Nat. Whewellite) - 146.12 - Colorless - R.I. α 1.495, β 1.565, γ 1.665 (K2)

Calcium oxide - CaO - 56.08 - Colorless - Cubic - D 3.32 (D8) - M.P. 2570 (K79) - T.P. 420 (I8) - B.P. 2850 (I8) - R.I. 1.837 (W42) - X-ray Lines 1.69, 2.39, 0.9974 (C30)

Calcium oxide, per-, hydrate - $CaO_2 \cdot 8H_2O$ - 216.21 - Colorless - Tetragonal - D 1.70 (N33)

Calcium phosphate - $CaO \cdot P_2O_5$ (α) - 198.04 - M.P. 984 (H64) - T.P. 963 (H64)

Calcium phosphate - $CaO \cdot P_2O_5$ (β) - 198.04 - Colorless - Tetragonal - D 2.82 (I8) - M.P. 977 (H64) - T.P. 550 (B109) - R.I. α 1.578, β 1.588, γ 1.593 (I8) - X-ray Lines 3.55, 2.83, 1.87 (B6)

Calcium phosphate - $CaO \cdot P_2O_5$ (Glass) - 198.04 - Colorless - R.I. 1.5477 (S117)

Calcium phosphate - $CaO \cdot 2P_2O_5$ - 340.00 - M.P. 810 (H64)

Calcium phosphate, pyro- - $2CaO \cdot P_2O_5$ (I) - 254.12 - M.P. 1353 (H64) - R.I. α 1.585, β 1.60, γ 1.605 (B6) - X-ray Lines 3.36, 2.000, 3.242 (B6)

Calcium phosphate, pyro- - $2CaO \cdot P_2O_5$ (II) - 254.12 - Colorless - Tetragonal - D 3.09 (I8) - Transition to I 1140 (H64) - R.I. α 1.624, β 1.628 (B6) - X-ray Lines 3.02, 2.80, 2.76 (B6)

Calcium phosphate - $2CaO \cdot 3P_2O_5$ - 538.04 - M.P. 774 (Incong.) (H64)

Calcium phosphate, ortho- - $3CaO \cdot P_2O_5$ (Nat. Whitlockite) - 310.20 - Colorless - Rhombohedral - D 3.12 (F69) - R.I. ω 1.629, ε 1.626 (F69) - X-ray Lines 2.85, 1.71, 3.17 (A41)

Calcium phosphate, ortho- - $3CaO \cdot P_2O_5$ (I) - 310.20 - Colorless - M.P. 1720 (B6) - R.I. α 1.588, γ 1.591 (B6) - X-ray Lines 2.90, 2.61, 3.92 (B6)

Calcium phosphate, ortho- - $3CaO \cdot P_2O_5$ (II) - 310.20 - Colorless - D 3.068^{16} (H91) - Transition to I 1350 (B6) - R.I. α 1.620, γ 1.622 (B6) - X-ray Lines 2.89, 2.60, 3.18 (B6)

Calcium phosphate - $4CaO \cdot P_2O_5$ - 366.28 - Colorless - Monoclinic - D 3.06 (I8) - M.P. 1700 (T50) - R.I. α 1.650, β 1.651, γ 1.656 (B13)

Calcium phosphate - $10CaO \cdot 3P_2O_5$ (Nat. Oxydapatite) - 986.68 - Colorless - Hexagonal - D 2.89 (I8) - M.P. 1540 (I8) - R.I. ω 1.633, ε 1.629 (L18)

Calcium phosphate chloride - $Ca_3(PO_4)_2 \cdot CaCl_2$ (Spodiosite) - 421.19 - Colorless - Rhombic - D 3.041^{23} (C6) - R.I. α 1.649, β 1.665, γ 1.670 (C6)

Calcium phosphate chloride - $3Ca_3(PO_4)_2 \cdot CaCl_2$ (Chloroapatite) - 1041.59 - Colorless - Hexagonal - D 3.010 (C6) - M.P. 1570 (T49) - R.I. ω 1.667, ε 1.666 (I8)

Calcium phosphate chloride fluoride - $3Ca_3(PO_4)_2 \cdot CaClF$ - 1025.14 - Colorless - D 3.14 (I8) - M.P. 1270 (I8) - R.I. ω 1.634, ε 1.631 (I8)

Calcium phosphate fluoride - $9CaO \cdot 3P_2O_5 \cdot CaF_2$ (Fluorapatite) - 1008.68 - Colorless - Hexagonal - D 3.18^{28} (I8) - M.P. 1630 (I8) - R.I. ω 1.6325, ε 1.629 (I8)

Calcium phosphate, hydrate - $CaO \cdot P_2O_5 \cdot H_2O$ - 216.06 - R.I. ω 1.578, ε 1.518 (B6) - X-ray Lines 3.35, 3.18, 3.76 (B6)

Calcium phosphate, hydrate - $CaO \cdot P_2O_5 \cdot 2H_2O$ - 234.07 - Colorless - Triclinic - D 2.546 (I8) - D.T. 268 (B6) - R.I. α 1.552, β 1.564. γ 1.590 (B6) - X-ray Lines 3.63, 3.48, 2.58 (B6)

Calcium phosphate, hydrate - $CaO \cdot P_2O_5 \cdot 3H_2O$ - 252.09 - Colorless - Triclinic - D 2.220 (I8) - $-2H_2O$ at 109; $-3H_2O$ at 325 (L23) - D.T. 153 (B6) - R.I. α 1.4932, β 1.5176, γ 1.5292 (L23) - X-ray Lines 3.90, 3.70, 11.8 (B6)

Calcium phosphate, hydrate - $2CaO \cdot P_2O_5 \cdot H_2O$ (Brushite) - 272.14 - Colorless - R.I. α 1.5412, β 1.5458, γ 1.553 (M32)

Calcium phosphate, hydrate - $2CaO \cdot P_2O_5 \cdot H_2O$ (Monetite) - 272.14 - Colorless - Triclinic - D 2.928 (G7) - R.I. α 1.60, β 1.61, γ 1.63 (B6) - X-ray Lines 3.35, 2.95, 2.74 (B6)

Calcium phosphate, hydrate - $2CaO \cdot P_2O_5 \cdot 5H_2O$ (Brushite) - 344.20 - Colorless - Triclinic - D 2.326 (T20) - $-2H_2O$ at 150; $-4H_2O$ at 185 (L23) - R.I. α 1.5392, β 1.5457, γ 1.5576 (L23) - X-ray Lines 2.60, 4.20, 3.20 (B6)

Calcium phosphate, hydrate - $4CaO \cdot P_2O_5 \cdot 5H_2O$ (Nat. Isoklasite) - 456.36 - Monoclinic - R.I. α 1.565, β 1.568, γ 1.580 (L11) (L12)

Calcium phosphate, hydrate - $5CaO \cdot 2P_2O_5 \cdot 1.5H_2O$ (Nat. Martinite) - 591.34 - R.I. α 1.590, β 1.602, γ 1.617 (L12)

Calcium phosphate, hydrate - $10CaO \cdot 3P_2O_5 \cdot H_2O$ - 1004.70 - Hexagonal - M.P. 1540 (B6) - R.I. 1.610 (B6) - X-ray Lines 2.79, 3.44, 1.94 (A40)

Calcium phosphate hydroxide - $3Ca_3(PO_4)_2 \cdot Ca(OH)_2$ (Hydroxyapatite) - 1004.70 - Colorless - Hexagonal - D 3.076 (B158) - D.T. 1400 (T49) - R.I. ω 1.6452, ε 1.6413 (B158)

Calcium selenate - $CaO \cdot SeO_3$ - 183.04 - Colorless - D 2.88 (H44)

Calcium selenate, hydrate - $CaO \cdot SeO_3 \cdot 2H_2O$ - 219.07 - Colorless - Monoclinic - D 2.68 (I8)

Calcium selenide - CaSe - 119.04 - Colorless - Cubic - D 3.57 (H44) - R.I. 2.274 (H1)

Calcium silicate - $CaO \cdot SiO_2$ (I) (Pseudo-Wollastonite) - 116.14 - Colorless - Monoclinic - D 2.904 (D9) - T.P. 1560 (K79) - R.I. α 1.610, β 1.611, γ 1.654 (I8) - X-ray Lines 1.966, 3.22, 2.79 (C30)

Calcium silicate - $CaO \cdot SiO_2$ (II) (Wollastonite) - 116.14 - Colorless - Triclinic (P24) - D 2.906^{21} (D9) - T.P. 1125 (O12) - R.I. α 1.616, β 1.629, γ 1.631 (I8) - X-ray Lines 2.97, 3.29, 1.823 (C30)

Calcium silicate - $CaO \cdot SiO_2$ (Nat. Parawollastonite) - 116.14 - Colorless - Monoclinic - R.I. α 1.620, β 1.631, γ 1.633 (P24)

Calcium silicate - $CaO \cdot SiO_2$ (Glass) - 116.14 - Colorless - D 2.904 (M77) - R.I. 1.6280 (L16)

Calcium silicate - $CaO \cdot 2SiO_2$ (Nat. Apophyllite) - 176.20 - Colorless - Hexagonal - R.I. ω 1.534, ε 1.537 (L10)

Calcium silicate - $2CaO \cdot SiO_2$ (I) - 172.22 - Colorless - Monoclinic - D 3.28 (S104) - M.P. 2130 (K79) - R.I. α 1.717, β -, γ 1.735 (M84) - X-ray Lines 2.77, 2.19, 2.62 (A40)

Calcium silicate - $2CaO \cdot SiO_2$ (II) - 172.22 - Rhombic - D 3.28 (D9) - T.P. 1420 (G62) - R.I. α 1.717, β -, γ 1.735 (I8) - X-ray Lines 2.77, 2.18, 2.73 (C30)

Calcium silicate - $2CaO \cdot SiO_2$ (II') - 172.22 - Colorless - Monoclinic - R.I. α -, β 1.715, γ - (R6)

Calcium silicate - $2CaO \cdot SiO_2$ (III) - 172.22 - Colorless - Monoclinic - D 2.97 (D9) - Transition to II 675 (I8) - R.I. α 1.642, β 1.645, γ 1.654 (I8) - X-ray Lines 1.901, 2.72, 3.00 (C30)

Calcium silicate - α-$2CaO \cdot SiO_2$ - 172.22 - Hexagonal, stable at high temperature (B86)

Calcium silicate - $3CaO \cdot SiO_2$ - 228.30 - Colorless - Monoclinic - M.P. 1900 (Incong.) (K79) - R.I. α 1.718, β -, γ 1.724 (L33) - X-ray Lines 2.60, 2.18, 1.766 (C30)

Calcium silicate - $3CaO \cdot 2SiO_2$ (Akermannite) - 288.36 - Colorless - Rhombic - M.P. 1475 (Incong.) (K79) - R.I. α 1.641, β 1.645, γ 1.650 (F12) - X-ray Lines 3.76, 3.15, 2.68 (A41)

Calcium silicate, boro- - $CaO \cdot B_2O_3 \cdot 2SiO_2$ (Nat. Danburite) - 245.84 - Colorless - Rhombic - D 3.0 (I8) - D.T. 996-1002 (K79) - R.I. α 1.630, β 1.633, γ 1.636 (L18) - X-ray Lines 3.59, 2.99, 2.73 (A41)

Calcium silicate, boro- - $5CaO \cdot B_2O_3 \cdot SiO_2$ - 410.10 - Colorless - M.P. 1419 (F30) - R.I. α 1.666, β -, γ 1.690 (F30)

Calcium silicate, boro-, hydrate - $2CaO \cdot B_2O_3 \cdot 2SiO_2 \cdot H_2O$ (Nat. Datolite) - 319.94 - Colorless - Monoclinic - D 3.0 (I8) - R.I. α 1.625, β 1.653, γ 1.669 (I8) - X-ray Lines 3.08, 2.81, 2.49 (A41)

Calcium silicate, boro-, hydrate - $4CaO \cdot 5B_2O_3 \cdot 2SiO_2 \cdot 5H_2O$ (Nat. Howlite) - 782.72 - Colorless - Monoclinic - D 2.6 (I8) - R.I. α 1.586, β 1.598, γ 1.605 (I8)

Calcium silicate, boro-, hydrate - $8CaO \cdot 5B_2O_3 \cdot 6SiO_2 \cdot 6H_2O$ (Nat. Bakerite) - 1265.30 - Colorless - D 2.8 (I8) - R.I. α -, β 1.583, γ - (I8)

Calcium silicate carbonate - $3CaO \cdot SiO_2 \cdot CO_2$ (Nat. Tilleyite) - 272.31 - Colorless - Monoclinic - D 2.823 (L18) - R.I. α 1.617, β 1.635, γ 1.652 (L18)

Calcium silicate carbonate - $4CaO \cdot 2SiO_2 \cdot CO_2$ (Spurrite) - 388.45 - Colorless - Rhombic and Trigonal - D 3.01 (I8) - T.P. 1200 (E9) - M.P. 1380 (122 atm. CO_2) (K79) - D.T. 1380 (122 atm.) (E9) - R.I. α 1.640, β 1.674, γ 1.679 (I8)

Calcium silicate carbonate - $4CaO \cdot 3SiO_2 \cdot 2CO_2$ (Nat. Scawtite) - 492.52 - Colorless - Monoclinic - D 2.77 (L18) - R.I. α 1.597, β 1.606, γ 1.621 (L18)

Calcium silicate, fluo- - $CaF_2 \cdot SiF_4$ - 182.14 - Colorless - Tetragonal - D 2.66 (L9) - X-ray Lines 3.83, 2.30, 1.91 (A40)

Calcium silicate, fluo-, hydrate - $CaF_2 \cdot SiF_4 \cdot 2H_2O$ - 218.17 - Colorless - X-ray Lines 5.3, 3.44, 4.25 (A40)

Calcium silicate fluoride - $3CaO \cdot 2SiO_2 \cdot CaF_2$ (Nat. Cuspidine) - 366.44 - Colorless - Monoclinic - D 2.92 (L18) - R.I. α 1.590, β 1.595, γ 1.602 (L18)

Calcium silicate, hydrate - $CaO \cdot SiO_2 \cdot H_2O$ - 134.16 - Colorless - R.I. α -, β 1.603, γ - (F28)

Calcium silicate, hydrate - $CaO\cdot 2SiO_2\cdot 2H_2O$ (Nat. Okenite) - 212.23 - Rhombic - D 2.3 (I8) - R.I. ω 1.530, ε 1.541 (F28) - X-ray Lines 8.87, 4.57, 3.56 (A41)

Calcium silicate, hydrate - $2CaO\cdot SiO_2\cdot H_2O$ - 190.24 - Needle - R.I. α -, β 1.598, γ - (K10)

Calcium silicate, hydrate - $2CaO\cdot SiO_2\cdot H_2O$ - 190.24 - Colorless - Lath-like Prism - D 2.8 (V10) - R.I. α 1.614, β 1.620, γ 1.633 (V10)

Calcium silicate, hydrate - $2CaO\cdot SiO_2\cdot H_2O$ (Nat. Hillebrandite) - 190.24 - Colorless - Rhombic - D 2.69 (I8) - R.I. α 1.605, β 1.61, γ 1.612 (I8) - X-ray Lines 2.91, 4.77, 1.86 (A41)

Calcium silicate, hydrate - $2CaO\cdot 2SiO_2\cdot 3H_2O$ (Nat. Crestmoreite) - 286.33 - Colorless - Monoclinic - R.I. α 1.593, β 1.603, γ 1.607 (F28)

Calcium silicate, hydrate - $2CaO\cdot 2SiO_2\cdot 3H_2O$ (Nat. Riversideite) - 286.33 - Colorless - D 2.64 (L18) - R.I. α 1.595, β 1.60, γ 1.603 (I8) - X-ray Lines 3.06, 2.80, 13.72 (A41)

Calcium silicate, hydrate - $2CaO\cdot 3SiO_2\cdot 2H_2O$ (Nat. Centrallasite) - 328.37 - Colorless - Monoclinic - R.I. α 1.535, β 1.548, γ 1.549 (B15)

Calcium silicate, hydrate - $2CaO\cdot 3SiO_2\cdot 2H_2O$ (Nat. Gyrolite) - 328.37 - Colorless - Trigonal - R.I. ω 1.548, ε 1.536 (F28) - X-ray Lines 3.36, 4.24, 2.85 (A41)

Calcium silicate, hydrate - $3CaO\cdot SiO_2\cdot 2H_2O$ - 264.33 - R.I. α 1.590, β -, γ 1.602 (F28)

Calcium silicate, hydrate - $3CaO\cdot 2SiO_2\cdot 3H_2O$ (Nat. Afwillite) - 342.41 - Colorless - Monoclinic - D 2.63 (L18) - R.I. α 1.617, β 1.620, γ 1.634 (F28) - X-ray Lines 2.82, 3.16, 2.71 (A41)

Calcium silicate, hydrate - $4CaO\cdot 4SiO_2\cdot 7H_2O$ (Nat. Crestmorite) - 590.67 - Colorless - Rhombic - D 2.22 (I8) - R.I. α 1.593, β 1.603, γ 1.607 (I8)

Calcium silicate, hydrate - $4CaO\cdot 5SiO_2\cdot 5H_2O$ (Tobermorite) - 614.70 - Acicular - R.I. α -, β 1.54, γ - (F28)

Calcium silicate, hydrate - $4CaO\cdot 7SiO_2\cdot 3H_2O$ (Nat. Centrallasite) - 698.79 - Colorless - Plate - D 2.51 (L18) - R.I. α 1.535, β 1.548, γ 1.549 (L18)

Calcium silicate, hydrate - $5CaO\cdot 3SiO_2\cdot 3H_2O$ (Nat. Foshagite) - 514.63 - Colorless - Rhombic - R.I. α 1.594, β 1.594, γ 1.598 (F28) - X-ray Lines 2.93, 1.82, 1.74 (A41)

Calcium silicate, hydrate - $5CaO\cdot 5SiO_2\cdot H_2O$ (Xonotlite) - 598.72 - Colorless - Rhombic - R.I. α 1.583, β 1.583, γ 1.594 (F28) - X-ray Lines 3.61, 4.22, 3.24 (A41)

Calcium silicate, hydrate - $6CaO\cdot 3SiO_2\cdot 2H_2O$ - 552.69 - Colorless - R.I. α 1.642, β -, γ 1.672 (F28)

Calcium silicate, hydrate - $6CaO\cdot 4SiO_2\cdot 3H_2O$ - 630.77 - Fibrous - R.I. α -, β 1.60, γ - (F28)

Calcium silicate, hydrate - $10CaO\cdot 5SiO_2\cdot 6H_2O$ - 969.20 - Colorless - Rhombic - R.I. α 1.614, β 1.620, γ 1.633 (F28)

Calcium silicate, phospho- - $3CaO\cdot P_2O_5\cdot 3SiO_2$ - 490.38 - M.P. 1630 (K79)

Calcium silicate, phospho- - $5CaO\cdot P_2O_5\cdot SiO_2$ - 482.42 - Colorless - D 3.01 (I8) - M.P. 1760 (I8)

Calcium silicate, phospho- - $5CaO \cdot P_2O_5 \cdot 2SiO_2$ (Silicocarnotite) - 542.48 - Colorless - M.P. >1770 (K79)

Calcium silicate, phospho- - $7CaO \cdot P_2O_5 \cdot 2SiO_2$ - 654.64 - Colorless - D 3.035 (N3) - R.I. α 1.652, β 1.675-1.642, γ 1.661 (N3) (B13) - X-ray Lines 2.85, 2.70, 1.960 (N3)

Calcium silicate, phospho- - $9CaO \cdot P_2O_5 \cdot 3SiO_2$ - 826.86 - Colorless - M.P. >1750 (K79)

Calcium silicate, phospho- - $16CaO \cdot 2P_2O_5 \cdot 5SiO_2$ - 1481.50 - Colorless - X-ray Lines 2.86, 2.70, 1.961 (N3)

Calcium sulfate - $CaSO_4$ (I) - 136.15 - Colorless - Monoclinic - M.P. 1300 (K15) - R.I. α 1.50, β -, γ 1.56 (W42) - X-ray Lines 3.49, 2.85, 2.32 (Form not defined) (A40)

Calcium sulfate - $CaSO_4$ (II) (Anhydrite) - 136.15 - Colorless - Rhombic or Monoclinic - D 2.960 (W61) - Transition to I 1195 (P56) - M.P. 1450 (K79) - D.T. 1230 (0.0127 atm.) (K79) - R.I. α 1.5693, β 1.5752, γ 1.6130 (I8) - X-ray Lines 6.05, 3.01, 2.80 (A41)

Calcium sulfate - $CaSO_4$ (III) ('Soluble Anhydrite') - 136.15 - Colorless - Hexagonal or Triclinic - D 2.61 (G8) - Transition to II >200 (P56) - R.I. ω 1.505, ε 1.548 (G8) - X-ray Lines 6.05, 3.01, 2.80 (A41)

Calcium sulfate, hydrate - $CaSO_4 \cdot \frac{1}{2}H_2O$ - 145.15 - Colorless - Monoclinic (B148) - D 2.58 (L50) - R.I. α 1.559, β 1.5595, γ 1.5836 (G15) - X-ray Lines 2.99, 2.80, 1.84 (A41)

Calcium sulfate, hydrate - $CaSO_4 \cdot 2H_2O$ (Gypsum) - 172.18 - Colorless - Monoclinic - D 2.3114 (W61) - Transition to $CaSO_4 \cdot \frac{1}{2}H_2O$ 97.5; Transition to $CaSO_4$ (II) 42 (P56) - R.I. α 1.5205, β 1.5224, γ 1.5296 (I8) - X-ray Lines 4.29, 3.06, 2.87 (A40)

Calcium sulfate, hydrate - $CaSO_4 \cdot 2D_2O$ - 176.20 - Colorless - $-2D_2O$ at 107 (B146)

Calcium sulfide - CaS - 72.15 - Colorless - Cubic - D 2.56 (A23) - R.I. 2.137 (H1) - X-ray Lines 2.84, 2.00, 1.268 (A40)

Calcium telluride - CaTe - 167.69 - Cubic - D 4.873 (H3) (S87) - R.I. >2.51 (H1)

Calcium tin (IV) borate - $CaO \cdot SnO_2 \cdot B_2O_3$ (Nat. Nordenskiöldine) - 276.42 - Colorless - Hexagonal - D 4.2 (I8) - R.I. ω 1.778, ε 1.660 (R4)

Calcium tin (IV) oxide - $CaO \cdot SnO_2$ - 206.78 - X-ray Lines 2.80, 3.98, 1.970 (A40)

Calcium tin (IV) silicate, hydrate - $CaO \cdot SnO_2 \cdot 3SiO_2 \cdot 2H_2O$ (Nat. Stokesite) - 422.99 - Rhombic - D 3.2 (I8) - R.I. α 1.609, β 1.6125, γ 1.619 (I8)

Calcium titanate - $CaO \cdot TiO_2$ - 135.98 - Colorless - Cubic, Rhombic - D 4.10 (I8) - M.P. 1975 (W19) - T.P. 1257 (N15) - R.I. 2.34 (L20) - X-ray Lines 2.69, 1.903, 1.552 (A40)

Calcium titanate - $2CaO \cdot TiO_2$ - 192.06 - M.P. 1800 (W19)

Calcium titanate - $3CaO \cdot TiO_2$ - 248.14 - M.P. 2135 (W19)

Calcium titanium antimonate - $5CaO \cdot 2TiO_2 \cdot 2Sb_2O_5$ (Nat. Lewisite) - 1087.24 - Honey Yellow - Cubic - D 4.95 (I8) - R.I. 2.20 (I8)

Calcium titanium silicate - $CaO \cdot TiO_2 \cdot SiO_2$ (Nat. Sphene) - 196.04 - X-ray 3.20, 2.59, 2.98 (A41)

Calcium titanium silicate - $CaO \cdot TiO_2 \cdot SiO_2$ (Titanite) - 196.04 - Colorless - Monoclinic - D 3.5 (I8) - M.P. 1382 (I20) - R.I. α 1.900, β 1.907, γ 2.034 (I8)

Calcium titanium sulfate - $CaTi(SO_4)_3$ - 376.18 - Colorless - Cubic - R.I. 1.4736 (I8)

Calcium tungstate - $CaO \cdot WO_3$ (Scheelite) - 288.00 - Colorless - Tetragonal - D 6.062 (Z24) - R.I. ω 1.9200, ϵ 1.9365 (Z29) - X-ray Lines 3.09, 4.76, 1.92 (A40)

Calcium uranium (VI) arsenate, hydrate - $CaO \cdot 2UO_3 \cdot As_2O_5 \cdot 8H_2O$ (Uranospinite) - 1002.17 - Rhombic (Tetragonal) - D 3.45 (I8) - R.I. ω 1.586, ϵ 1.56 (L11); α 1.560, β 1.582, γ 1.587 (I8)

Calcium uranium (IV) carbonate, hydrate - $2CaO \cdot UO_2 \cdot 4CO_2 \cdot 10H_2O$ (Nat. Uranothallite) - 576.29 - Rhombic - D 2.8 (I8) - R.I. α 1.500, β 1.503, γ 1.537 (L12)

Calcium uranium (VI) oxide - $CaO \cdot UO_3$ - 342.15 - Yellow Green - Rhombohedral - D 7.45 (X-ray) (Z15)

Calcium uranium (VI) phosphate, hydrate - $CaO \cdot 2UO_3 \cdot P_2O_5 \cdot 8H_2O$ (Bassite) - 914.31 - Monoclinic - D 3.10 (I8) - R.I. α 1.56, β 1.574, γ 1.580 (I8)

Calcium uranium (VI) phosphate, hydrate - $CaO \cdot 2UO_3 \cdot P_2O_5 \cdot 8H_2O$ (Bassite) - 914.31 - Rhombic - D 3.1 (I8) - R.I. α 1.553, β 1.575, γ 1.577 (I8)

Calcium uranium (VI) silicate, hydrate - $CaO \cdot 2UO_3 \cdot 2SiO_2 \cdot 6H_2O$ (Nat. Uranophane) - 856.44 - Triclinic - D 3.9 (I8) - R.I. α 1.643, β 1.666, γ 1.670 (L11)

Calcium uranium (VI) vanadate, hydrate - $CaO \cdot 2UO_3 \cdot V_2O_5 \cdot 9.3H_2O$ (Nat. Uranovanadate) - 977.67 - Amorphous (M28)

Calcium vanadate - $CaO \cdot V_2O_5$ - 237.98 - M.P. 778 (M86)

Calcium vanadate - $CaO \cdot 2V_2O_5$ - 419.88 - M.P. 637 (I8)

Calcium vanadate - $2CaO \cdot V_2O_5$ - 294.06 - M.P. 1015 (M86)

Calcium vanadate - $3CaO \cdot V_2O_5$ - 350.14 - M.P. 1380 (M86)

Calcium vanadate, hydrate - $CaO \cdot V_2O_5 \cdot 2H_2O$ (Nat. Metarossite) - 274.01 - Yellow - R.I. α 1.840, β >1.850, γ >1.850 (F47)

Calcium vanadate, hydrate - $CaO \cdot V_2O_5 \cdot 4H_2O$ (Nat. Rossite) - 310.04 - Yellow - Triclinic - D 2.45 (W42) - R.I. α 1.710, β 1.770, γ 1.840 (F47)

Calcium vanadate, hydrate - $CaO \cdot 3V_2O_5 \cdot 9H_2O$ (Nat. Hewettite) - 763.92 - Rhombic - D 2.554 (I8) - R.I. α 1.77, β 2.18, γ 2.35 (I8)

Calcium vanadate, hydrate - $CaO \cdot 3V_2O_5 \cdot 9H_2O$ (Nat. Metahewettite) - 763.92 - Rhombic - D 2.51 (I8) - R.I. α 1.70, β 2.10, γ 2.23 (I8)

Calcium vanadate, hydrate - $2CaO \cdot 3V_2O_5 \cdot 11H_2O$ (Nat. Pascoite) - 856.03 - Monoclinic - D 2.46 (I8) - R.I. α 1.775, β 1.815, γ 1.825 (I8)

Calcium yttrium fluoride - $3CaF_2 \cdot 2YF_3$ - 526.08 - R.I. 1.45 (L10)

Calcium yttrium fluoride - $5CaF_2 \cdot 2YF_3$ - 682.24 - Colorless - Hexagonal - D 3.19 (W42a) - R.I. ω 1.45, ϵ - (W42a)

Calcium zinc arsenate - $3CaO \cdot 4ZnO \cdot 2As_2O_5$ (Nat. Brickerite) - 953.40 - Colorless - Triclinic - D 4.13 (A5) - R.I. α 1.752, β 1.755, γ 1.779 (A5)

Calcium zinc arsenate, hydrate - $2CaO \cdot 2ZnO \cdot As_2O_5 \cdot H_2O$ (Nat. Austinite) - 522.76 - Colorless - Rhombic - D 4.12 (S93) - R.I. α 1.759, β 1.763, γ 1.783 (S93)

Calcium zinc silicate - $2CaO \cdot ZnO \cdot SiO_2$ (Nat. Hardystonite) - 253.60 - Colorless - Tetragonal - D 3.4 (I8) - R.I. ω 1.669, ε 1.657 (I8)

Calcium zinc silicate - $2CaO \cdot ZnO \cdot 2SiO_2$ (Nat. Hardystonite) - 313.66 - Colorless - Tetragonal - R.I. ω 1.6722, ε 1.6609 (H85)

Calcium zinc silicate, hydrate - $CaO \cdot ZnO \cdot SiO_2 \cdot H_2O$ (Nat. Klinoedrite) - 215.54 - Colorless - Monoclinic - D 3.33 (I8) - R.I. α -, β 1.670, γ - (I8)

Calcium zirconate - $CaO \cdot ZrO_2$ - 179.30 - Colorless - Monoclinic - D 4.78 (R72) - M.P. 2345 (L11)

Carbon - C - 12.010 - Black - M.P. 3700 (A19) (U2) - S.P. 4827 (A20)

Carbon - C (Nat. Diamond) - 12.010 - Colorless - D 3.51540^{20} (H102) - R.I. 2.4173 (I8) - X-ray Lines 2.06, 1.26, 1.07 (A41)

Carbon - C (Graphite) - 12.010 - Black - Hexagonal - D 2.22^{20} (A20) - M.P. >4727 (B126) - S.P. 4327 (B126) - X-ray Lines 3.36, 1.23, 1.15 (A41)

Carbon - C (Transparent Graphite) - 12.010 - Transparent - Hexagonal Flakes - D 2.15 (P47) - R.I. 2.0 (P47)

Carbon chloride, tetra- - CCl_4 - 153.838 - Colorless Liquid - D 1.58413^{25} (G72); 1.925^{-78} (Solid) (B70) - M.P. -22.870 (J26) - T.P. -47.66 (J26) - B.P. 76.71 (G72) - R.I. 1.46044^{20} (Z47)

Carbon (II) fluoride - CF - 31.01 - Hexagonal - D 2.67 (R60)

Carbon fluoride - C_6F_{12} - 300.06 - D 1.93^{23} (C27) - M.P. 58.2 (Confined) (C27) - T.P. -105 (C27) - S.P. 51 (760 m.m.) (C27)

Carbon fluoride, tetra- - CF_4 - 88.01 - Colorless Gas - D 1.98^{-195} (K46) - M.P. -186.8 (K46) - T.P. -196.94 (A19) - B.P. -127.9 (K13)

Carbon oxide, mono- - CO - 28.010 - Colorless Gas - D 0.8138^{-195} (I8) - M.P. -205.01 (K15) - T.P. -211.6 (C40) - B.P. -191.47 (A19)

Carbon oxide, di- - CO_2 - 44.010 - Colorless Gas - D 1.53^{-79} (I8) - M.P. -57.5 (K15) - S.P. -78.5 (K13)

Carbon selenide, di- - CSe_2 - 169.93 - Golden Yellow Liquid - D 2.679 (G73) - M.P. -45.5 (G73) - B.F. 124 (G73) - R.I. 1.8454 (G73)

Carbon sulfide, di- - CS_2 - 76.14 - Colorless Liquid - D 1.2622^{20} (I8) - M.F. 110.8 (K15) - B.F. 46.3 (K13) - R.I. 1.6276^{20} (M29)

Cerium - Ce - 140.13 - Iron Gray - Cubic - D 6.789 (T52) - M.P. 600 (A19) (U2) - T.P. 540, 710, 740 (L59) - B.P. 1400 (A20) - X-ray Lines 2.97, 2.57, 1.815 (A40)

Cerium - Ce - 140.13 - Steel Gray - Hexagonal - D 6.74 (T52)

Cerium (III) carbonate fluoride - $CeFCO_3$ (Nat. Bastnaesite) - 219.14 - Hexagonal - D 5.0 (I8) - R.I. ω 1.717, ε 1.817 (I8)

Cerium (III) chloride - $CeCl_3$ - 246.50 - Colorless - Hexagonal - D 3.97 (K37) - M.P. 848 (K79)

Cerium (IV) chromite - $CeO_2 \cdot Cr_2O_3$ - 324.15 - M.P. 2440 (K79)

Cerium (III) chromite - $Ce_2O_3 \cdot Cr_2O_3$ (or $2CeO_2 \cdot Cr_2O_3$) - 480.28 - M.P. 2430 (W15)

Cerium (III) fluoride - CeF_3 (Fluocerite) - 197.13 - Colorless - Hexagonal - D 5.8 (I8) - M.F. 1460 (W12) - R.I. ω 1.613, ε 1.607 (I8)

Cerium (IV) fluoride - CeF_4 - 216.13 - Colorless - D 3.1-4.77 (K47)

Cerium (III) molybdate - $Ce_2O_3 \cdot 3MoO_3$ - 760.11 - Yellow - Tetragonal D 4.83 (I8) - M.P. 973 (I8) - R.I. ω 2.019, ε 2.007 (6670A) (I8)

Cerium (III) nitrate, hydrate - $Ce(NO_3)_3 \cdot 6H_2O$ - 434.25 - X-ray Lines 6.3, 4.70, 4.39 (A40)

Cerium (III) oxide - Ce_2O_3 - 328.26 - Grayish Green - Trigonal - D 6.86 (X-ray) (Z2) - M.P. 1692 (I8)

Cerium (IV) oxide - CeO_2 - 172.13 - Brownish White - Cubic - D 7.132^{23} (R64) - M.P. >2600 (W16) - Partly Decomposed 2500 (K79) - X-ray Lines 1.92, 1.64, 1.11 (A41)

Cerium (III) oxide sulfide - Ce_2O_2S - 344.33 - Hexagonal - D 5.99 (X-ray) (Z22)

Cerium (III) phosphate - $Ce_2O_3 \cdot P_2O_5$ (Nat. Monazite) - 470.22 - Red and Yellow - Monoclinic, Rhombic - D 5.22 (I8) - R.I. α 1.795, β -, γ - (L11)

Cerium (III) phosphate - $Ce_2O_3 \cdot P_2O_5$ (I) - 470.22 - Monoclinic - D 5.234 (X-ray) (M67)

Cerium (III) phosphate - $Ce_2O_3 \cdot F_2O_5$ (II) - 470.22 - Hexagonal - D 4.193 (X-ray) (M67)

Cerium (III) phosphate - $Ce_2O_3 \cdot 3P_2O_5$ - 754.14 - Needle - D 3.27 (I8)

Cerium (IV) phosphate, hydrate - $3CeO_2 \cdot 2P_2O_5 \cdot 11H_2O$ - 998.49 - Pale Green - $-6H_2O$ at 200, $-11H_2O$ at 500 (A42)

Cerium (III) selenide - Ce_2Se_3 - 517.14 - Bluish Black - D 6.34 (K48)

Cerium (IV) selenide - Ce_2Se_4 - 596.10 - D 6.53 (K48)

Cerium silicide - $CeSi_2$ - 196.25 - Triclinic - D 5.41 (X-ray) (Z22a)

Cerium (IV) sulfate - $Ce(SO_4)_2$ - 332.26 - Deep Yellow - D 3.91^{18} (B24) - D.T. 195 (P13)

Cerium (III) sulfate - $Ce_2(SO_4)_3$ - 568.46 - Colorless to Green - Monoclinic or Rhombic - D 3.912 (I8) - D.T. 920 (746 m.m.) (P13) - X-ray Lines 5.5, 2.85, 3.03 (A40)

Cerium (III) sulfate, hydrate - $Ce_2(SO_4)_3 \cdot 5H_2O$ - 658.54 - Monoclinic - D 3.17 (I8)

Cerium (III) sulfate, hydrate - $Ce_2(SO_4)_3 \cdot 8H_2O$ - 712.59 - Smoke Pink - Triclinic - D 2.886^{17} (I8) - $-8H_2O$ at 630 (I8)

Cerium (III) sulfate, hydrate - $Ce_2(SO_4)_3 \cdot 9H_2O$ - 730.60 - Hexagonal - D 2.831 (I8)

Cerium (III) sulfide - Ce_2S_3 - 376.46 - Yellow - Cubic - D 5.10^{25} (K49) - M.P. 2100 (in vacuum) (P46)

Cerium (IV) sulfide - Ce_2S_4 - 408.52 - D 4.90^{25} (K49)

Cerium (III) tungstate - $Ce_2O_3 \cdot 3WO_3$ - 1024.02 - Yellow - Monoclinic - D 6.653^{20} (N16) - M.P. 1060 (N16)

Cerium (III) tungstate - $Ce_2O_3 \cdot 3WO_3$ - 1024.02 - Pale Yellow - Tetragonal - D 6.77^{17} (I8) - M.P. 1089 (I8)

Cesium - Cs - 132.91 - Cubic - D 1.9^{20} (A20) - M.P. 28 (A20) - B.P. 690 (A20)

Cesium aluminum fluoride - $3CsF \cdot AlF_3$ - 539.70 - M.P. 823 (I8)

Cesium aluminum silicate, hydrate - $Cs_2O \cdot Al_2O_3 \cdot 4SiO_2 \cdot H_2O$ (Nat. Pollucite) - 642.02 - Cubic - D 2.9 (I8) - R.I. 1.517 (S110)

Cesium beryllium fluoride - $2CsF \cdot BeF_2$ - 350.84 - Colorless - D 4.213^{30} (R10)

Cesium borate, fluo- - $CsF \cdot BF_3$ - 219.73 - Rhombic - D 3.305 (Z31) - M.P. 550 (B83) - R.I. α -, β 1.36, γ - (Z31)

Cesium carbonate - Cs_2CO_3 - 325.83 - Colorless - Needle - D.T. 1447 (760 m.m.) (K14)

Cesium chlorate, per- - $CsClO_4$ - 232.37 - Rhombic - D 3.37 (X-ray) (S119) - X-ray Lines 3.98, 2.82, 2.41 (at 230°C) (A41)

Cesium chloride - CsCl (I) - 168.37 - Colorless - Cubic - M.P. 638 (K79) - B.P. 1300 (K13) - X-ray Lines 2.90, 1.681, 1.102 (Form not defined) (A40)

Cesium chloride - CsCl (II) - 168.37 - Colorless - Cubic - D 3.983 (W58) - Transition to I 445 (W1) - R.I. 1.63966^{26} (W58)

Cesium chromate - $Cs_2O \cdot CrO_3$ - 381.83 - Yellow - Rhombic, Trigonal - D 4.35 (X-ray) (M53)

Cesium chromate, di- - $Cs_2O \cdot 2CrO_3$ - 481.84 - R.I. ω >1.95, ε >1.95 (T2)

Cesium fluoride - CsF - 151.91 - D 4.115 (H43) - X-ray Lines 2.99, 2.12, 3.47 (A40)

Cesium fluoride - CsF (I) - 151.91 - Colorless - Cubic - D 5.34 (R12) - M.P. 684 (W20) - B.P. 1251 (K13) - R.I. 1.578 (S86)

Cesium fluoride - CsF (II) - 151.91 - Colorless - Cubic - D 4.52 (X-ray) (P64) - R.I. 1.478 (P64)

Cesium fluoride, acid - $CsF \cdot HF$ - 171.92 - M.P. 176.0 (W47)

Cesium fluoride, acid - $CsF \cdot 2HF$ - 191.93 - M.P. 50.2 (W47)

Cesium fluoride, acid - $CsF \cdot 3HF$ - 211.93 - M.P. 32.6 (W47)

Cesium fluoride, acid - $CsF \cdot 6HF$ - 271.96 - M.P. -42.3 (W47)

Cesium formate - $CsHCO_2$ - 177.93 - Colorless - Prisms - M.P. 265 (S54)

Cesium gallium sulfide - $Cs_2S \cdot Ga_2S_3$ - 533.52 - Light Yellow - Rhombic - D 3.56 (I18) - M.P. 980 (I18) - R.I. >1.78 (I18)

Cesium germanium fluoride - $2CsF \cdot GeF_4$ - 452.42 - Colorless - Cubic - D 4.107 (X-ray) (S20) - R.I. 1.430 (S20) - X-ray Lines 3.188, 1.836, 2.248 (A40)

Cesium hydroxide - CsOH - 149.92 - Colorless - Cubic - D 3.675^{11} (I8) M.P. 272.3 (I8) - T.P. 223 (I8)

Cesium iron (III) fluoride - $3CsF \cdot FeF_3$ - 568.58 - Cubic - D 3.3 (M56)

Cesium lanthanum fluoride - $3CsF \cdot LaF_3$ - 651.65 - M.P. 795 (D18)

Cesium manganate, per- - $CsMnO_4$ - 251.84 - Dark Violet - Rhombic - D 3.60 (I8) - D.T. 320 (C58)

Cesium nitrate - $CsNO_3$ (I) - 194.92 - Colorless - Cubic - D 3.685 (I8) - M.P. 407 (K15) - B.P. 740 (L56) - X-ray Lines 3.15, 1.99, 1.82 (Form not defined) (A40)

Cesium nitrate - $CsNO_3$ (II) - 194.92 - Colorless - Hexagonal - Transition to I 161 (I8) - R.I. ω 1.55, ε 1.56 (W42)

Cesium nitrate, acid- - $CsNO_3 \cdot HNO_3$ - 257.93 - Colorless - Cubic - M.P. 100 (I8)

Cesium nitrate, acid- - $CsNO_3 \cdot 2HNO_3$ - 320.95 - Colorless - Plates - M.P. 35 (I8)

Cesium oxide - Cs_2O - 281.82 - Pale Yellow - Hexagonal - D 4.36 (I8) - M.P. 490 (in Na) (R18) - X-ray Lines 3.45, 2.92, 3.15 (A41)

Cesium oxide, per- - Cs_2O_2 - 297.82 - Pale Yellow - Needle - D 4.47 (R17) - M.P. 594 (C19) - D.T. 1074 (760 m.m.) (C19)

Cesium oxide, per- - CsO_2 - 164.91 - Tetragonal - D 3.80 (X-ray) (H35) - X-ray Lines 3.80, 3.14, 3.63 (A41)

Cesium phosphate, fluo- - $CsF \cdot PF_5$ - 277.89 - D 3.32^{19} (L14)

Cesium plutonium (IV) chloride - $2CsCl \cdot PuCl_4$ - 717.66 - Trigonal - D 4.10 (X-ray) (Z13)

Cesium rhenate - $Cs_2O \cdot Re_2O_7$ - 383.22 - Rhombic - D 4.76 (S68) - D.T. 616 (S68)

Cesium selenate - $Cs_2O \cdot SeO_3$ - 408.78 - Rhombic - D 4.456 (T56) - R.I. α 1.599, β 1.600, γ 1.600 (I8)

Cesium selenide - Cs_2Se - 344.78 - Colorless - D.T. 660 (B38)

Cesium silicate, fluo- - $2CsF \cdot SiF_4$ - 407.88 - Colorless - Cubic - D 3.372^{17} (I8) - R.I. 1.391 (S20)

Cesium sulfate - Cs_2SO_4 - 361.89 - Colorless - Rhombic, Hexagonal - D 4.243 (I8) - M.P. 1010 (I8) - T.P. 660 (I8) - R.I. α 1.560, β 1.564, γ 1.566 (I8) - X-ray Lines 3.28, 3.14, 2.27 (A40)

Cesium sulfate, acid- - $CsHSO_4$ - 229.98 - Colorless - Rhombic - D 3.352^{18} (I8) - R.I. ω 1.505, ε 1.50 (T2)

Cesium sulfide, per- - Cs_2S_2 - 329.95 - Dark Red - M.P. 460 (I8)

Cesium titanium fluoride - $2CsF \cdot TiF_4$ - 427.72 - M.P. 690 (G31)

Cesium tungstate - $Cs_2O \cdot WO_3$ - 513.74 - Colorless - M.P. 958 (S88) - T.P. 520, 501 (S88) - D.T. 950 (S88)

Cesium yttrium fluoride - $3CsF \cdot YF_3$ - 601.65 - M.P. 1075 (D18)

Chloric acid, per- - $HClO_4$ - 100.465 - Colorless Liquid - D 1.768^{20} (W67) - M.P. -112 (W67) - B.P. 130 (Extrapolated) (H16)

Chlorine - Cl (Cl_2) - 35.457 - Yellowish Green Gas - Tetragonal - M.P. -101 (A20) - B.P. -34.05 (G24)

Chlorine oxide, di- - ClO_2 - 67.457 - Yellowish Liquid - D 1.642^{0} (C21) - M.P. -59 (K33) - B.P. 11.0 (K33)

Chlorine oxide, tri- - Cl_2O_6 - 166.914 - Deep Red Liquid - D 1.65 (I8) - M.P. -1 (I8)

Chlorine oxide, hept- - Cl_2O_7 - 182.914 - Colorless Liquid - M.P. -91.5 (G51) - B.P. 80 (G51)

Chromium - Cr - 52.01 - Grayish White - Cubic - D $7.103^{22.3}$ (H60) - M.P. 1890 (A20) - B.P. 2500 (A20) - X-ray Lines 2.048, 1.183, 0.915 (A40)

Chromium carbide - Cr_3C_2 - 180.05 - Gray - D 6.68 (R12) - M.P. 1890 (R12) - B.P. 3800 (R12) - X-ray Lines 2.30, 2.23, 1.945 (A40)

Chromium (II) chloride - $CrCl_2$ - 122.92 - D 2.878^{25} (B53) - M.P. 824 (F22)

Chromium (III) chloride - $CrCl_3$ - 158.38 - Violet - Trigonal - O 2.782^{25} (B53) - M.P. ~ 1150 (F22)

Chromium (II) fluoride - CrF_2 - 90.01 - Grey - Monoclinic - D 4.11 (I8) - M.P. 1100 (I8) - B.P. >1300 (I8)

Chromium (III) fluoride - CrF_3 - 109.01 - Green - Rhombic - D 3.8 (I8) - M.P. >1000 (I8) - S.P. 1100-1200 (M29)

Chromium (III) fluoride, hydrate - $CrF_3 \cdot 4H_2O$ - 181.07 - Green - Cubic - D 3.78 - X-ray Lines 4.70, 4.09, 2.57 (A40)

Chromium (III) fluoride, oxy- - CrOF - 87.01 - Olive-Green - D 4.20 (W14)

Chromium (III) nitrate - $Cr(NO_3)_3$ - 238.03 - D.T. 166 (1 atm.) (K79)

Chromium (III) nitrate, hydrate - $Cr(NO_3)_3 \cdot 9H_2O$ - 400.18 - Purple - Rhombic - M.P. 36.5 (M29) - D.T. 100 (M29) - X-ray Lines 4.04, 6.7, 6.3 (A40)

Chromium (III) oxide - Cr_2O_3 - 152.02 - Green - Triclinic, Hexagonal - D 5.21 (I8) - M.P. 2435 (W15) - B.P. >3000 (K79) - R.I. Mean 2.5 (W42) - X-ray Lines 1.67, 1.43, 2.66 (A41)

Chromium (IV) oxide - CrO_2 - 84.01 - Brown-Black - Tetragonal (M51) (G87) - -O at 300 (R12)

Chromium (VI) oxide - CrO_3 - 100.01 - Red - Rhombic - D 2.811^{29} (H91) - M.P. 198 (Incong.) (K79) - D.T. 267-348 (V4) - X-ray Lines 3.40, 4.20, 2.86 (A40)

Chromium (III) phosphate, meta- - $Cr_2O_3 \cdot 3F_2O_5$ - 577.90 - Green - Rhombic - D 2.97 (I8)

Chromium (III) phosphate - $2Cr_2O_3 \cdot 3P_2O_5$ - 729.92 - Green - Monoclinic - D 3.2 (I8)

Chromium (III) phosphate, hydrate - $Cr_2O_3 \cdot P_2O_5 \cdot 4H_2O$ - 366.04 - Green - D 2.42^{33} (M29)

Chromium (III) phosphate, hydrate - $Cr_2O_3 \cdot P_2O_5 \cdot 8H_2O$ - 438.11 - Green - D 2.10^{33} (M29)

Chromium (III) phosphate, hydrate - $Cr_2O_3 \cdot P_2O_5 \cdot 12H_2O$ - 510.17 - Violet - Triclinic - D 2.12^{33} (I8)

Chromium (II) selenide - CrSe - 130.97 - Black - Hexagonal - D 6.74 (X-ray) (J37) - X-ray Lines 2.81, 2.19, 1.84 (A41)

Chromium (III) silicate, hydrate - $Cr_2O_3 \cdot 2SiO_2 \cdot 2H_2O$ (Nat. Volchonskite) - 308.17 - Monoclinic (?) - R.I. α -, β 1.585, γ - (L12)

Chromium (III) sulfate - $Cr_2(SO_4)_3$ - 392.22 - Violet Red - D 3.0 (I8) - D.T. 777 (1 atm.) (K79)

Chromium (III) sulfate, hydrate - $Cr_2(SO_4)_3 \cdot 18H_2O$ - 716.51 - Green - Cubic - D 1.7 ($17H_2O$) (I8) - R.I. 1.564 (W42)

Chromium (II) sulfide - CrS - 84.08 - Black - Hexagonal - D 4.1 (I8) - M.P. 1550 (P41) - X-ray Lines 2.08, 2.67, 3.00 (A41)

Chromium (II, III) sulfide - $CrS \cdot Cr_2S_3$ - 284.29 - Greenish Black - D 3.54^{14} (W25)

Chromium (III) sulfide - Cr_2S_3 - 200.22 - Black - D 3.7 (I8) - D.T. 1350 (M29)

Chromium telluride - CrTe - 179.61 - X-ray Lines 2.98, 1.26, 1.98 (A41)

Cobalt - Co - 58.94 - Gray with reddish tinge - Hexagonal - D 8.9^{20} (A20) - M.P. 1495 (V1) - T.P. 850 (K79) - B.P. 2900 (A20) - X-ray Lines 1.92, 2.03, 2.17 (A40)

Cobalt (II) aluminate - $CoO \cdot Al_2O_3$ (Cobalt Blue) - 176.88 - Blue - Cubic - D 4.37^{18} (I8) - M.P. 1960 (W18) - R.I. >1.78 (Red-Light) (M41) - X-ray Lines 1.42, 2.43, 1.55 (A41)

Cobalt (II) aluminate - $4CoO \cdot 3Al_2O_3$ - 605.58 - D 4.80 (I8)

Cobalt arsenic sulfide - CoAsS (Cobaltite) - 165.92 - Cubic - D 6.26 (X-ray) (S119) - X-ray Lines 2.50 2.28, 1.074 (A41)

Cobalt borate - $CoO \cdot B_2O_3$ - 144.58 - X-ray Lines 2.44, 2.88, 1.555 (A40)

Cobalt (II) borate, fluo- - $CoF_2 \cdot 2BF_3$ - 232.58 - Pseudorhombic - R.I. α -, β 1.40, γ - (D19)

Cobalt (II) carbonate - $CoCO_3$ (Sphaerocobaltite) - 118.95 - Red - Trigonal - D 4.124 (B49) - D.T. 341 (760 m.m.) (K102) - R.I. ω 1.855, ε 1.60 (I8) - X-ray Lines 2.76, 1.71, 3.64 (A40)

Cobalt (II) chloride - $CoCl_2$ - 129.85 - Blue - Hexagonal - D 3.356^{25} (I8) - M.P. 727 (K15) - B.P. 1049 (I8) - X-ray Lines 5.80, 1.77, 1.70 (A40)

Cobalt (II) chromate - $CoO \cdot CrO_3$ - 174.95 - Grey-Black - Rhombic - D 4.10 (X-ray) (S119) (B119) - X-ray Lines 2.62, 3.30, 3.10 (A40)

Cobalt (II) chromite - $CoO \cdot Cr_2O_3$ - 226.96 - Cubic - D 5.143 (N9) - X-ray Lines 2.51, 1.467, 1.599 (A40)

Cobalt (II) columbate - $CoO \cdot Cb_2O_5$ - 340.76 - Dark Blue - D 5.56^{17} (M29)

Cobalt (II) fluoride - CoF_2 - 96.94 - Rose Red - Monoclinic - D 4.46^{25} (B78) - M.P. >1000 (B69)

Cobalt (III) fluoride - CoF_3 - 115.94 - Light Brown - Hexagonal - D 3.88 (R69) - X-ray Lines 3.66, 1.83, 1.66 (A41)

Cobalt (II) iron (III) oxide - $CoO \cdot Fe_2O_3$ - 234.64 - Black - Cubic - D 5.3 (N9) (H39) - M.P. 1570 (A34) - X-ray Lines 2.51, 1.476, 1.608 (A40)

Cobalt (II) nitrate - $Co(NO_3)_2$ - 182.96 - Pale Rose - D 2.49 (Calc.) (C31) - D.T. 226 (1 atm.) (K79)

Cobalt (II) nitrate, hydrate - $Co(NO_3)_2 \cdot 3H_2O$ - 237.00 - Rhombic - M.P. 91 (I8)

Cobalt (II) nitrate, hydrate - $Co(NO_3)_2 \cdot 6H_2O$ - 291.05 - Red - Monoclinic - D 1.883^{25} (I8) - M.P. 55.5 (V8) - R.I. α 1.38, β -, γ 1.52 (W42) - X-ray Lines 4.60, 3.29 2.19 (A40)

Cobalt (II) oxalate - CoC_2O_4 - 146.96 - Reddish White - D 3.021^{25} (B78) - X-ray Lines 4.73, 2.95, 3.60 (A40)

Cobalt (II) oxide - CoO - 74.94 - Greenish Brown - Cubic - D 6.455 (W6) - M.P. 1800 (W19) - X-ray Lines 2.12, 1.50, 2.45 (A40)

Cobalt (II,III) oxide - $CoO \cdot Co_2O_3$ - 240.82 - Black - Cubic - D 6.07 (I8) - D.T. (1 atm. O_2) 970, Transition to CoO (K79) - X-ray Lines 2.43, 1.432, 1.56 (A40)

Cobalt (III) oxide - Co_2O_3 - 165.88 - Gray - Hexagonal - D 5.18 (I8) - X-ray Lines 2.87, 2.33, 1.78 (A41)

Cobalt (II) oxide, hydrate - $CoO \cdot H_2O$ - 92.96 - Rose Red - Rhombic - D 3.597^{15} (I8) - $-H_2O$ at 168 (10 m.m.) (K79) - X-ray Lines 2.68, 4.00, 1.58 (α form); 2.37, 1.79, 4.66 (β form) (A41)

Cobalt (III) oxide, hydrate - $Co_2O_3 \cdot 3H_2O$ - 219.93 - Brownish Black - D 4.47 (N11) - $-3H_2O$ at 280 (N11)

Cobalt (II) phosphate, ortho- - $3CoO \cdot P_2O_5$ - 366.78 - Violet - D 2.587^{25} (B78) - X-ray Lines 4.33, 3.44, 2.42 (A40)

Cobalt (II) phosphate, hydrate - $3CoO \cdot P_2O_5 \cdot 8H_2O$ - 510.91 - Reddish - D 2.769^{25} (R12) - $-8H_2O$ at 200 (R12) - X-ray Lines 6.7, 2.95, 2.69 (A40)

Cobalt (II) selenate - $CoO \cdot SeO_3$ - 201.90 - D 4.037 (G41)

Cobalt (II) selenate, hydrate - $CoO \cdot SeO_3 \cdot 5H_2O$ - 291.98 - Triclinic - D 2.512 (G41)

Cobalt (II) selenate, hydrate - $CoO \cdot SeO_3 \cdot 6H_2O$ - 310.00 - Monoclinic - D 2.32 (I8) - R.I. α 1.47, β 1.5225, γ 1.5227 (W42)

Cobalt (II) selenate, hydrate - $CoO \cdot SeO_3 \cdot 7H_2O$ - 328.01 - Monoclinic - D 2.135 (I8)

Cobalt (II) selenide - CoSe - 137.90 - Yellow - Hexagonal - D 7.65 (I8)

Cobalt (II) silicate, meta- - $CoO \cdot SiO_2$ - 135.00 - Dark Violet - M.P. 1000 (Incong.) (R61)

Cobalt (II) silicate, ortho- - $2CoO \cdot SiO_2$ - 209.94 - Violet - Rhombic - D 4.677^{25} (B67) - M.P. 1345 (B67)

Cobalt (II) silicate, fluo-, hydrate - $CoF_2 \cdot SiF_4 \cdot 6H_2O$ - 309.10 - Pink - Trigonal - D 2.09 (I8) - R.I. ω 1.382, ε 1.387 (I8)

Cobalt (II) sulfate - $CoSO_4$ - 155.01 - Red - Hexagonal - D 3.710^{25} (I8) - M.P. 989 (K79) - D.T. 904 (760 m.m.) (W51) - X-ray Lines 3.40, 4.82, 3.08 (A40)

Cobalt (II) sulfate, hydrate - $CoSO_4 \cdot H_2O$ - 173.02 - Red - Monoclinic - D 3.075 (M58) - $-H_2O$ at 285 (D13) - R.I. α 1.603, β 1.639, γ 1.683 (L19)

Cobalt (II) sulfate, hydrate - $CoSO_4 \cdot 4H_2O$ - 227.07 - Red - D 2.368^{25} (I8) - Transition to $CoSO_4 \cdot H_2O$ at 120-220 (D13)

Cobalt (II) sulfate, hydrate - $CoSO_4 \cdot 5H_2O$ - 245.09 - Triclinic - D 2.13 (T28) - R.I. α 1.529, β 1.546, γ 1.548 (L19)

Cobalt (II) sulfate, hydrate - $CoSO_4 \cdot 6H_2O$ - 263.10 - Monoclinic - D 2.029^{25} (I8) - Transition to $CoSO_4 \cdot 4H_2O$ at 95 (D13) - R.I. α 1.531, β 1.549, γ 1.552 (L19)

Cobalt (II) sulfate, hydrate - $CoSO_4 \cdot 7H_2O$ (Bieberite) - 281.12 - Pink - Monoclinic and Rhombic - D 1.948 (I8) - Transition to $CoSO_4 \cdot 6H_2O$ at 66 (D13) - R.I. α 1.477, β 1.483, γ 1.489 (I8)

Cobalt (II) sulfide - CoS (Jaipurite) - 91.01 - M.P. >1125 (K79)

Cobalt (II) sulfide - CoS (Sycpoorite) - 91.01 - Red - Cubic - D 5.55 (H92) - M.P. >1116 (G41) - X-ray Lines 1.909, 3.11, 1.625 (A40)

Cobalt (II,III) sulfide - $CoS \cdot Co_2S_3$ (Linnaeite) - 305.08 - Dark Gray - Cubic - D 4.9 (I8) - D.T. 480 (J33) - X-ray Lines 1.67, 2.82, 1.82 (A41)

Cobalt (III) sulfide - Co_2S_3 - 214.08 - Black - D 4.8 (G41)

Cobalt (IV) sulfide - CoS_2 - 123.07 - Black - Cubic - D 4.73 (H92)

Cobalt (II) telluride - CoTe - 186.55 - Brown - D 8.85 (X-ray) (J37)

Cobalt (II) tin (IV) oxide - $2CoO \cdot SnO_2$ - 300.58 - Cubic - D 6.108 (N8) - X-ray Lines 1.52, 1.12, 2.60 (A41)

Cobalt (II) titanate - $CoO \cdot TiO_2$ - 154.84 - X-ray Lines 2.72, 2.53, 1.706 (A40)

Cobalt (II) titanate - $2CoO \cdot TiO_2$ - 229.78 - Greenish Black - Cubic - D 5.07 (H87) - X-ray Lines 1.49, 2.54, 1.62 (A41)

Cobalt (II) tungstate - $CoO \cdot WO_3$ - 306.86 - Greenish Blue - Monoclinic - D 8.42 (G41)

*Columbium - Cb - 92.91 - White - Cubic - D 8.57^{20} (A20) - M.P. 2415 (A20) - B.P. >3300 (A20) - X-ray Lines 2.33, 1.34, 1.65 (A40)

Columbium carbide - CbC - 104.92 - M.P. 3700-3800 (R12) - X-ray Lines 2.54, 2.20, 1.55 (A41)

Columbium chloride - $CbCl_5$ - 270.20 - Yellowish White - Acicular - D 2.75 (I8) - M.P. 194 (I8) - B.P. 240.5 (I8)

Columbium fluoride - CbF_5 - 187.91 - Colorless - Monoclinic - D 3.29 (I8) - M.P. 75.5 (I8) - B.P. 225 (K13)

Columbium (II) oxide - CbO - 108.91 - Black - Cubic - D 7.30 (B120)

---

*By action of the International Union of Chemistry, Amsterdam, Holland, September 9, 1949, the official name is niobium, symbol Nb.

Columbium (III) oxide - Cb_2O_3 - 233.82 - Black or Bluish Gray - M.P. 1777 (F61)

Columbium (IV) oxide - CbO_2 - 124.91 - Black - Tetragonal - D 6.15 (X-ray) (S119) (F53)

Columbium oxide - Cb_2O_5 - 265.82 - Colorless - Rhombic - D 4.457^{25} (L12) - M.P. (in O_2) 1460 (B120) - T.P. 850 (B120)

Copper - Cu - 63.54 - Red - Cubic - D 8.96^{20} (A20) - M.P. 1083.0 (A20) - B.P. 2600 (A20) - X-ray Lines 2.08, 1.81, 1.28 (A41)

Copper (II) aluminate - $CuO \cdot Al_2O_3$ - 181.48 - Chocolate Color - Cubic - D 4.732^{18} (P15) - X-ray Lines 2.43, 1.423, 2.85 (A40)

Copper (II) aluminum phosphate, hydrate - $CuO \cdot 3Al_2O_3 \cdot 2P_2O_5 \cdot 9H_2O$ (Nat. Turquoise) - 831.42 - Triclinic - D 2.67 (I8) - R.I. α 1.61, β 1.62, γ 1.65 (I8) (L12)

Copper (I) aluminum sulfide - $4Cu_2S \cdot Al_2S_3$ - 786.72 - Metallic Gray - D 5.790 (M60) - M.P. 1110 (M60)

Copper (I) antimony (III) sulfide - $Cu_2S \cdot Sb_2S_3$ (Chalcostibite) - 498.87 - X-ray Lines 3.10, 2.98, 1.75 (A41)

Copper (I) antimony (V) sulfide - $3Cu_2S \cdot Sb_2S_5$ (Famatinite) - 881.30 - X-ray Lines 3.06, 1.87, 1.59 (A41)

Copper (I) arsenic (V) sulfide - $3Cu_2S \cdot As_2S_5$ (Enargite) - 787.60 - X-ray Lines 3.23, 3.09, 2.86 (A41)

Copper (I) bismuth (III) sulfide - $Cu_2S \cdot Bi_2S_3$ (Emplectite) - 673.35 - X-ray Lines 3.21, 3.03, 3.10 (A41)

Copper (I) bismuth (III) sulfide - $3Cu_2S \cdot Bi_2S_3$ (Nat. Wittichenite) - 991.64 - Rhombic - D 6.33 (B101) - X-ray Lines 3.12, 1.78, 2.32 (A41)

Copper (I) bismuth (III) sulfide - $3Cu_2S \cdot 2Bi_2S_3$ (Klaprotholite) - 1505.85 - X-ray Lines 4.57, 2.85, 3.07 (A41)

Copper (II) borate - $CuO \cdot B_2O_3$ - 149.18 - Bluish Green - Needle - D 3.86 (I8) - M.P. 970 (G85) - D.T. 875 (G85)

Copper (II) borate - $CuO \cdot B_2O_3$ (Glass) - 149.18 - Blue - D 3.61 (G85)

Copper (II) carbonate, oxy- - $2CuO \cdot CO_2$ (Nat. Mysorine) - 203.09 - D 4.398 (I8)

Copper (II) carbonate, basic- - $CuCO_3 \cdot Cu(OH)_2$ (Nat. Malachite) - 221.11 - Dark Green - Monoclinic - D 4.0 (I8) - D.T. 200 (K79) - R.I. α 1.655, β 1.875, γ 1.909 (I8) - X-ray Lines 2.86, 3.68, 5.1 (A40)

Copper (II) carbonate, basic- - $2CuCO_3 \cdot Cu(OH)_2$ (Nat. Azurite) - 344.66 - Blue - Monoclinic - D 3.88 (I8) - D.T. 200 (K79) - R.I. α 1.730, β 1.758, γ 1.838 (I8) - X-ray Lines 3.51, 5.1, 2.51 (A40)

Copper (I) chloride - Cu_2Cl_2 (Nantokite) - 197.99 - Colorless - Cubic - D 4.136^{30} (W66) - M.P. 430 (K15) - B.P. 1490 (K13) - R.I. 1.973 (H4)

Copper (II) chloride - $CuCl_2$ (Eriochalcite) - 134.45 - Brownish Yellow - D 3.387^{25} (B57) - M.P. 630 (B57) - B.P. 993 (I8)

Copper (II) chromate - $CuO \cdot CrO_3$ - 179.55 - Rhombic - D 4.18 (X-ray) (S119) (B119)

Copper (I) chromite - $Cu_2O \cdot Cr_2O_3$ - 295.10 - D 7.0 (S109) - D.T. 600-700 (S109) - X-ray Lines 2.470, 1.646, 2.85 (S109)

Copper (II) cobalt (III) oxide - $CuO \cdot Co_2O_3$ - 245.42 - Black - Cubic - D 6.28 (X-ray) (H88) - X-ray Lines 2.43, 1.421, 1.55 (A40)

Copper cobalt sulfide - $CuCo_2S_4$ (Carrollite) - 309.68 - Cubic - D 4.86 (X-ray) (S119) (F53) - X-ray Lines 1.68, 2.88, 1.83 (A41)

Copper (I) fluoride - Cu_2F_2 - 165.08 - Red - D 7.07 (X-ray) (E3) - M.P. 908 (I8) - S.P. 1100-1200 (M29)

Copper (II) fluoride - CuF_2 - 101.54 - Colorless - Monoclinic or Triclinic - D 4.23 (E3) - M.P. 950 (W10)

Copper (II) fluoride, acid-, hydrate - $CuF_2 \cdot 5HF \cdot 6H_2O$ - 309.68 - Blue - Monoclinic - D 2.405 (I8) - R.I. α 1.395, β 1.440, γ 1.444 (E4)

Copper (II) fluoride, hydrate - $CuF_2 \cdot 2H_2O$ - 137.57 - Blue - Monoclinic - D 2.934^{26} (B69) - X-ray Lines 4.73, 2.57, 1.98 (A40)

Copper (II) formate - $Cu(HCO_2)_2$ - 153.58 - Blue - Monoclinic - D 1.831 (I8) - X-ray Lines 4.90, 4.60, 2.61 (A40)

Copper (II) hydroxide - $Cu(OH)_2$ - 97.56 - Blue - D 3.368 (M29)

Copper (I) iron (III) oxide - $Cu_2O \cdot Fe_2O_3$ - 302.78 - Black - Hexagonal - D 5.47 (W22) - M.P. 1458 (M29) - X-ray Lines 2.50, 2.84, 2.23 (A41)

Copper (II) iron (III) oxide - $CuO \cdot Fe_2O_3$ - 239.24 - Brownish Black - D 5.28 (M29)

Copper (II) iron (III) oxide - $CuO \cdot Fe_2O_3$ (I) - 239.24 - Steel Gray - Cubic - D 5.3 (W22) - M.P. 1560 (A34) - R.I. 2.71 (L58)

Copper (II) iron (III) oxide - $CuO \cdot Fe_2O_3$ (II) - 239.24 - Brown - Tetragonal - D 5.29 (W22) - Transition to I 350 (W22)

Copper (II) iron (III) oxide - $2CuO \cdot 3Fe_2O_3$ - 638.18 - D 5.241^{20} (H65)

Copper (II) iron (II) sulfide - $CuS \cdot FeS$ (Chalcopyrite) - 183.52 - Tetragonal - D 4.21 (X-ray) (S119) - M.P. 470 (K17) - X-ray Lines 3.03, 1.86, 1.59 (A41)

Copper (II) iron (II) sulfide - $CuS \cdot 2FeS$ (Cubonite) - 271.45 - X-ray Lines 3.23, 1.88, 1.75 (A41)

Copper(I) lead (II) bismuth sulfide - $Cu_2S \cdot 2PbS \cdot Bi_2S_3$ (Nat. Aikinite) - 1151.91 - Orthorhombic - D 7.08 (P26) - X-ray Lines 3.67, 3.18, 2.88 (A40)

Copper (II) manganese (III) oxide - $CuO \cdot Mn_2O_3$ (Crednerite) - 237.40 - X-ray Lines 2.49, 2.84, 2.40 (A41)

Copper (II) nitrate, hydrate - $Cu(NO_3)_2 \cdot 3H_2O$ - 241.60 - Blue - D 2.047 (I8) - M.P. 114.49 (I8) - D.T. 174 (I8) - X-ray Lines 5.8, 4.04, 2.63 (A40)

Copper (II) nitrate, hydrate - $Cu(NO_3)_2 \cdot 6H_2O$ - 295.65 - Pale Blue - Rhomboidal - M.P. 26.4 (Incong.) (I8)

Copper (I) oxide - Cu_2O (Cuprite) - 143.08 - Red - Cubic - D 6.0 (I8) - M.P. 1230 (K15) - T.P. 56 (A48) - D.T. 1800 (M29) - R.I. 2.705 (I8) - X-ray Lines 2.45, 1.51, 2.12 (A40)

Copper (II) oxide - CuO (Tenorite or Melaconite) - 79.54 - Black - Monoclinic, Cubic - D 6.35 (R64) - M.P. 1447 (K15) - R.I. α -, β 2.84, γ - (P63) - X-ray Lines 2.52, 2.32, 1.86 (A41)

Copper (II) oxide - CuO (Nat. Tenorite) - 79.54 - Black - Triclinic - D 6.45 (L18) - D.T. 1026 (153 m.m. O_2) (I8) - R.I. α -, β 2.63, γ - (I8) - X-ray Lines 2.51, 2.31, 1.85 (A40)

Copper (II) phosphate, hydrate - $3CuO \cdot P_2O_5 \cdot 3H_2O$ - 434.63 - Blue - Rhombic - X-ray Lines 9.9, 3.02, 6.9 (A40)

Copper (II) phosphate, hydrate - $4CuO \cdot P_2O_5 \cdot H_2O$ (Nat. Libethenite) - 478.14 - Olive Green - Rhombic - D 3.7 (I8) - R.I. α 1.702, β 1.745, γ 1.789 (I8) - X-ray Lines 4.81, 2.63, 2.91 (A40)

Copper (II) phosphate, hydrate - $4CuO \cdot P_2O_5 \cdot 2H_2O$ (Nat. Pseudolibethenite) - 496.15 - D 4.0 (I8)

Copper (II) phosphate, hydrate - $4CuO \cdot P_2O_5 \cdot 3H_2O$ (Nat. Tagilite) - 514.17 - Green - Monoclinic - D 4.08 (I8) - R.I. α 1.69, β 1.84, γ 1.85 (I8)

Copper (II) phosphate, hydrate - $5CuO \cdot P_2O_5 \cdot 2H_2O$ (Nat. Dihydrite) - 575.69 - Green - Monoclinic or Triclinic - D 4.2 (I8) - R.I. α 1.719, β 1.762, γ 1.805 (I8)

Copper (II) phosphate, hydrate - $6CuO \cdot P_2O_5 \cdot 3H_2O$ (Nat. Cornetite) - 673.25 - Greenish Blue - Rhombic - D 4.1 (L18) - R.I. α 1.765, β 1.81, γ 1.82 (L18)

Copper (II) selenate, hydrate - $CuO \cdot SeO_3 \cdot 5H_2O$ - 296.58 - Blue - Triclinic - D 2.559 (I8)

Copper (I) selenide - Cu_2Se - 206.04 - Dark Gray - Cubic - D 6.749^{30} (I8) - M.P. 1113 (I8) - T.F. 110 (K12) - X-ray Lines 1.38, 4.53, 2.28 (A41)

Copper (I) selenide - Cu_2Se (Nat. Berzelianite) - 206.04 - X-ray Lines 1.98, 3.20, 1.84 (A41)

Copper (I,II) selenide - Cu_3Se_2 (Umangite) - 348.54 - D.T. <800 (1 atm.) (K79)

Copper (II) selenide - CuSe (Klockmannite) - 142.50 - Bluish Black - Needles - D 6.67 (M29) - X-ray Lines 3.25, 2.90, 2.00 (A41)

Copper (II) selenite - $2CuO \cdot SeO_2$ - 270.04 - Yellowish Green - Monoclinic - D 4.913^{25} (G10)

Copper (II) selenite, hydrate - $CuO \cdot SeO_2 \cdot 2H_2O$ (Chalcomenite) - 226.53 - Blue - Monoclinic, Rhombic - D 3.312^{25} (G10) - R.I. α 1.710, β 1.731, γ 1.732 (I8)

Copper (II) silicate, fluo-, hydrate - $CuSiF_6 \cdot 6H_2O$ - 313.70 - Blue - Rhombic - D 2.158^{18} (I8) - R.I. ω 1.409, ε 1.408 (I8)

Copper (II) silicate, hydrate - $CuO \cdot SiO_2 \cdot H_2O$ (Nat. Bisbeeite) - 157.62 - Colorless - Rhombic - R.I. α 1.61, β 1.62, γ 1.71 (I8)

Copper (II) silicate, hydrate - $CuO \cdot SiO_2 \cdot H_2O$ (Nat. Dioptase) - 157.62 - Green - Trigonal - D 3.05 (I8) - R.I. ω 1.655, ε 1.708 (L18) - X-ray Lines 7.5, 2.62, 5.0 (A41)

Copper (II) silicate, hydrate - $CuO \cdot SiO_2 \cdot 2H_2O$ (Chrysocolla) - 175.64 - X-ray Lines 3.35, 1.81, 1.37 (A41)

Copper (II) silicate, hydrate - $2CuO \cdot 2SiO_2 \cdot H_2O$ (Nat. Plancheite) - 297.22 - Blue - Monoclinic - D 3.36 (L18) - R.I. α 1.645, β 1.660, γ 1.715 (L18)

Copper (II) silicate, hydrate - $2CuO \cdot 2SiO_2 \cdot H_2O$ (Nat. Shattuckite) - 297.22 - Blue - Monoclinic - R.I. α 1.752, β 1.782, γ 1.815 (I8)

Copper (II) silicate, thio- - $4CuS \cdot SiS_2$ - 474.62 - D 4.975 (M59) - M.P. 1195 (M59)

Copper (II) sulfate - $CuSO_4$ (Hydrocyanite) - 159.61 - Greenish White - Rhombic - D 3.542^{25} (M58) - M.P. 200 (I8) - D.T. 650 (B76) - R.I. α 1.724, β 1.733, γ 1.739 (P63) - X-ray Lines 2.62, 4.20, 3.55 (A40)

Copper (II) sulfate, hydrate - $CuSO_4 \cdot 5H_2O$ (Chalcanthite) - 249.69 - Blue - Monoclinic - D 2.282^{25} (M58) - T.P. 28.90, 34.85, 53.70 (B143) - $-H_2O$ at 96.5, $-2H_2O$ at 102, $-4H_2O$ at 113 (T15) - R.I. α 1.5140, β 1.5368, γ 1.5434 (P63) - X-ray Lines 4.70, 4.00, 3.70 (A40)

Copper (II) sulfate, oxy- - $CuSO_4 \cdot CuO$ (Dolerophanite) - 239.15 - Brown - Monoclinic - R.I. α -, β 1.777, γ - (W42)

Copper (I) sulfide - Cu_2S (I) - 159.15 - Black - Cubic - D 5.76 (F5) - M.P. 1127 (K15)

Copper (I) sulfide - Cu_2S (II) - 159.15 - Black - Rhombic - D 5.5-5.6 (M29) - Transition to I 103 (K17) - M.P. 1130 (vacuum) (K79) - X-ray Lines 1.97, 2.79, 3.22 (A41)

Copper (II) sulfide - CuS (Covellite) - 95.61 - Black - Hexagonal, Monoclinic - D 4.64^{21} (A24) - T.P. 103 (I8) - D.T. 358 (in H_2S) (P57) - R.I. ω 1.45, ϵ - (P57) or 2.10-2.15 (C63) - X-ray Lines 2.81, 1.89, 3.04 (A41)

Copper (I) telluride - Cu_2Te - 254.69 - T.P. 351, 387 (C23) - M.P. 880 (K79)

Copper (I,II) telluride - Cu_4Te_3 (Rickardite) - 636.99 - X-ray Lines 2.06, 3.31, 1.98 (A41)

Copper (II) telluride - CuTe - 191.15 - M.P. 640 (Incong.) (K79) - T.P. 380 (K79)

Copper (II) uranium (VI) arsenate - $CuO \cdot 2UO_3 \cdot As_2O_5$ (Zeunerite) - 881.50 - Tetragonal - D 3.2 (8 H_2O) (I8) - R.I. ω 1.645, ϵ 1.623 (I8)

Copper (II) uranium (VI) arsenate, hydrate - $CuO \cdot 2UO_3 \cdot As_2O_5 \cdot 8H_2O$ (Nat. Metazeunerite) - 1025.63 - Rhombic - R.I. ω 1.585, ϵ 1.576 (L12)

Copper (II) uranium (VI) phosphate, nydrate - $CuO \cdot 2UO_3 \cdot P_2O_5 \cdot 8H_2O$ (Metatorferrite) - 937.77 - Tetragonal - D 3.5 (I8) - R.I. ω 1.623, ϵ 1.625 (I8) (L11)

Copper (II) uranium (VI) phosphate, hydrate - $CuO \cdot 2UO_3 \cdot P_2O_5 \cdot 12H_2O$ (Nat. Torbernite) - 1009.83 - Tetragonal - D 3.5 (I8) - R.I. α 1.582, β 1.592, γ 1.592 (I8) (L12)

Copper (I) vanadate, thio- - Cu_3VS_4 (Sulvanite) - 369.83 - Cubic - D 3.27 (X-ray) (S119) - X-ray Lines 1.91, 5.39, 3.11 (A41)

Copper (II) zinc fluoride - $CuF_2 \cdot ZnF_2$ - 204.92 - M.P. 801 (M78) - R.I. ω 1.465, ϵ 1.455 (M78)

Curium - $_{96}Cm$ - Synthetic element with mass numbers 240 and 242 for the known isotopes (S45)

Dysprosium - Dy - 162.46 - Hexagonal (A20) - D 8.44 (B94) - X-ray Lines 2.72, 1.51, 1.79 (A41)

Dysprosium chloride - $DyCl_3$ - 268.83 - Pale Olive Green - Plate - D 3.60 (K37) - M.P. 654 (J16)

Dysprosium hydroxide - $Dy(OH)_3$ - 213.48 - Hexagonal - D 5.83 (X-ray) (F56)

Dysprosium oxide - Dy_2O_3 - 372.92 - Colorless - Cubic, Rhombic - D 7.81^{27} (I8)

Dysprosium phosphate, hydrate - $Dy_2O_3 \cdot P_2O_5 \cdot 10H_2O$ - 695.04 - Colorless with Yellow Tint - $-10H_2O$ at >200 (J17)

Dysprosium selenide - Dy_2Se_3 - 561.80 - Blue Black - D ~ 7.72 (K48)

Dysprosium sulfate, hydrate - $Dy_2(SO_4)_3 \cdot 8H_2O$ - 757.25 - Yellow - D 3.119^{20} (H53) - $-8H_2O$ at 360 (M29)

Dysprosium sulfide - Dy_2S_3 (I) - 421.12 - Brownish Violet - D 6.50 (K49)

Dysprosium sulfide - Dy_2S_3 (II) - 421.12 - Yellowish Brown - D 6.08 (K49) - Transition to I 1000 (K49)

Erbium - Er - 167.2 - Hexagonal - D 9.16 (X-ray) (A20)
Erbium chloride - $ErCl_3$ - 273.6 - Clear Red - Plates - D 4.1 (B102) - M.P. 774 (J16)
Erbium hydroxide - $Er(OH)_3$ - 218.2 - Hexagonal - D 6.18 (X-ray) (F56)
Erbium oxide - Er_2O_3 - 382.4 - Red - Cubic - D 8.64 (I8) - B.P. 3000 (M88) - X-ray Lines 3.06, 1.87, 1.59 (A40)
Erbium selenide - Er_2Se_3 - 571.3 - Ocher Yellow and Brownish Black - D 6.96 (K48)
Erbium silicate - $Er_2O_3 \cdot SiO_2$ - 442.5 - Rose (S95)
Erbium sulfate - $Er_2(SO_4)_3$ - 622.6 - Colorless - D 3.678 (I8) - D.T. 1000 (668 m.m.) (P13)
Erbium sulfate, hydrate - $Er_2(SO_4)_3 \cdot 8H_2O$ - 766.7 - Rose Red - D 3.205^{20} (H54)
Erbium sulfide - Er_2S_3 - 430.6 - Yellowish White - D 6.05^{25} (K49)

Europium - Eu - 152.0 - Steel Gray - Cubic - D 5.30 (B94) - X-ray Lines 3.23, 1.87, 1.22 (A41)
Europium (II) chloride - $EuCl_2$ - 222.9 - Colorless - D 4.87^{27} (B20) - X-ray Lines 2.73, 3.83, 3.52 (A41)
Europium (III) chloride - $EuCl_3$ - 258.4 - Colorless - D 4.471^{25} (M49) - M.P. 623 (J15)
Europium (II) fluoride - EuF_2 - 190.0 - Yellow - Cubic - D 6.495 (B26)
Europium (III) oxide - Eu_2O_3 - 352.0 - Colorless with Reddish-Yellowish Tint - Cubic and Rhombic - D 7.42^{18} (I8) - T.P. ~ 740 (P13)
Europium (II) sulfate - $EuSO_4$ - 248.1 - Rhombic (P21) - D 4.985^{23} (M17)
Europium (III) sulfate, hydrate - $Eu_2(SO_4)_3 \cdot 8H_2O$ - 736.3 - Pale Rose - D 2.972^{20} (U1) - $-8H_2O$ at 375 (M29)
Europium (II) sulfide - EuS - 184.1 - Brownish Violet - Cubic - D 5.884 (N36)

Fluorine - F (F_2) - 19.00 - Yellow Gas - M.P. -223 (A19) (U2) - B.P. -187.17 (A20)

Francium - $_{87}Fr$ - Synthetic element with mass numbers 219, 220, 221, and 223 for the known isotopes (S45)

Gadolinium - Gd - 156.9 - Hexagonal - D 7.95 (X-ray) (A20)
Gadolinium chloride - $GdCl_3$ - 263.3 - Colorless - Monoclinic - D 4.52 (I8) - M.P. 765 (K79)
Gadolinium formate - $Gd(HCO_2)_3$ - 292.0 - Rhombohedral - D 3.77 (P5) - R.I. ω 1.7379, ε 1.7091 (P2)
Gadolinium hydroxide - $Gd(OH)_3$ - 207.9 - Hexagonal - D 5.75 (X-ray) (F56)
Gadolinium nitrate, hydrate - $Gd(NO_3)_3 \cdot 5H_2O$ - 433.0 - Monoclinic - D 2.406^{18} (I8) - M.P. 92 (I8)
Gadolinium nitrate, hydrate - $Gd(NO_3)_3 \cdot 6H_2O$ - 451.0 - Triclinic - D 2.332 (I8) - M.P. 91 (I8)

Gadolinium oxide - Gd_2O_3 - 361.8 - Yellow - Cubic, Rhombic - D 7.407^{15} (I8)

Gadolinium selenate - $Gd_2O_3 \cdot 3SeO_3$ - 742.7 - D 4.175^{15} (P13)

Gadolinium selenate, hydrate - $Gd_2O_3 \cdot 3SeO_3 \cdot 8H_2O$ - 886.8 - Pearly - Prismatic - D 3.309 (P13)

Gadolinium selenate, hydrate - $Gd_2O_3 \cdot 3SeO_3 \cdot 10H_2O$ - 922.8 - Rhombic - D 3.048 (P13)

Gadolinium sulfate - $Gd_2(SO_4)_3$ - 602.0 - Colorless - D 4.139^{15} (I8)

Gadolinium sulfate, hydrate - $Gd_2(SO_4)_3 \cdot 8H_2O$ - 746.1 - Monoclinic - D 3.010^{15} (I8)

Gadolinium sulfide - Gd_2S_3 - 410.0 - Yellow - D 6.16^{25} (K49)

Gallium - Ga - 69.72 - Grayish White - Rhombic, one face-centered orthorhombic (A20) - D 5.903^{25} (C55) - M.P. 29.78 (A19) (U2) - B.P. 2071 (A20) - X-ray Lines 3.27, 1.99, 1.95 (A41)

Gallium (II) chloride - $GaCl_2$ - 140.63 - Colorless - M.P. 170.5 (L29) - B.P. 535 (I8)

Gallium (III) chloride - $GaCl_3$ - 176.09 - Colorless - Needle - D 2.47^{25} (K53) - M.P. 77.0 (L29) - B.P. 200.0 (L29)

Gallium (III) fluoride - GaF_3 - 126.72 - D 4.47^{25} (H12) - M.P. >1000 (E6) - B.P. $\sim$ 1000 (H12)

Gallium (I) oxide - Ga_2O - 155.44 - Brownish Black - D 4.77^{25} (K55) - S.P. 500 (in vacuum) (B141)

Gallium (III) oxide - Ga_2O_3 - 187.44 - D 5.95 (L61)

Gallium (III) oxide - Ga_2O_3 (I) - 187.44 - Colorless - Monoclinic or Rhombic - D 5.88^{25} (X-ray) (K55) - M.P. 1740 (W18)

Gallium (III) oxide - Ga_2O_3 (II) - 187.44 - Colorless - Hexagonal - D 6.44 (X-ray) (Z7) - Transition to I 600 (L26) - R.I. α 1.92, β -, γ 1.95 (L26)

Gallium (III) oxide, hydrate - $Ga_2O_3 \cdot H_2O$ - 205.46 - Colorless - Prism - R.I. 1.84 (L26)

Gallium (I) selenide - Ga_2Se - 218.40 - Black - D 5.02^{25} (K55)

Gallium (II) selenide - GaSe - 148.68 - Dark Reddish Brown - Plate - D 5.03 (K55) - M.P. 960 (K55)

Gallium (III) selenide - Ga_2Se_3 - 376.32 - Reddish Black - D 4.92^{25} (K55) - M.P. >1020 (K55)

Gallium (III) sulfate - $Ga_2(SO_4)_3$ - 427.64 - Colorless - D.T. 690 (760 m.m.) (M10)

Gallium (I) sulfide - Ga_2S - 171.51 - Black or green - D 4.18^{25} (K55)

Gallium (II) sulfide - GaS - 101.79 - Yellow - D 3.86^{25} (K55) - M.P. 965 (K55)

Gallium (III) sulfide - Ga_2S_3 - 235.64 - Yellow - D 3.65^{25} (K55) - M.P. 1255 (in vacuum) (B140)

Gallium (II) telluride - GaTe - 197.33 - Black - Leaflet - D 5.44^{25} (K55) - M.P. 824 (K55)

Gallium (III) telluride - Ga_2Te_3 - 522.27 - Black - D 5.57^{25} (K55) - M.P. 790 (K55)

Germanium - Ge - 72.60 - Grayish White - Cubic - D 5.36^{20} (A20) - M.P. 958.5 (in H_2) (K79) - B.P. 2700 (A20); volatilize 1350 (K79)

Germanium chloride - $GeCl_4$ - 214.43 - Colorless - Liquid - D 1.879^{20} (L30) - M.P. -49.5 (I8) - B.P. 84 (K13) - R.I. 1.4638^{20} (L30)

Germanium fluoride - GeF_4 - 148.60 - Colorless gas - D 3.148^{-195} (F25) - M.P. -15 (3022 m.m.) (D16) - S.P. -35 (F25)

Germanium (II) oxide - GeO - 88.60 - Yellow - D 1.825^{21} (S39) - S.P. 710 (in N_2) (D15)

Germanium oxide - GeO_2 (I) (Soluble Form) - 104.60 - Colorless - Hexagonal - D 4.228^{25} (L28) - M.P. 1116 (L28) - R.I. ω 1.695, ε 1.735 (L28) - X-ray Lines 3.43, 1.56, 1.42 (Form not defined) (A41)

Germanium oxide - GeO_2 (II) (Insoluble Form) - 104.60 - Colorless - Tetragonal - D 6.239^{25} (L28) - Transition to I 1033 - Meta-stable M.P. 1086 (L28) - Volatilize >1250 (K79) - R.I. ω 1.99, ε 2.05-2.10 (L28)

Germanium oxide - GeO_2 (Glass) - 104.60 - Colorless - D 3.6277^{20} (M77) - R.I. 1.6081 (S117)

Germanium (II) selenide - GeSe - 151.56 - Tetragonal - D 5.30^{25} (I15) - M.P. 667 (I15)

Germanium selenide - $GeSe_2$ - 230.52 - Rhombic - D 4.56^{25} (I15) - M.P. 707 (I15)

Germanium sulfate - $Ge(SO_4)_2$ - 264.73 - Colorless - D 3.92^{22} (S42) - Decomposition begins 200 (S42)

Germanium (II) sulfide - GeS - 104.67 - Black - Crystalline - D 3.78^{20} (D15) - M.P. 625 (D15)

Germanium (II) sulfide - GeS - 104.67 - Dark Red - Amorphous - D 3.31^{20} (D15)

Germanium sulfide - GeS_2 - 136.73 - Colorless - Rhombic - D 2.942^{14} (P71) - M.P. 800 (P71)

Germanium sulfide - GeS_2 (Glass) - 136.73 - Amber, Transparent - D 5.81 (P71) - R.I. 2.10 (S117)

Germanium (II) telluride - GeTe - 200.21 - Metallic Color - D 6.20^{25} (K45) - M.P. 725 (Incong.) (K45)

Germanium tungsten vanadate, hydrate - $GeO_2 \cdot 10WO_3 \cdot V_2O_5 \cdot 8H_2O$ - 2749.83 - D 4.98 (I16)

Germanium tungsten vanadate, hydrate - $GeO_2 \cdot 10WO_3 \cdot V_2O_5 \cdot 16H_2O$ - 2893.97 - Cubic - D 5.54 (I16)

Germanium ungsten vanadate, hydrate - $GeO_2 \cdot 10WO_3 \cdot V_2O_5 \cdot 32H_2O$ - 3182.21 - Orange - ~Tetragonal - D 4.24 (I16) - R.I. >1.774 (I16)

Glucinum - See Beryllium

Gold - Au - 197.2 - Yellow - Cubic - D 19.32^{20} (A20) - M.P. 1063.0 (A19) (A20) (U2) (I8a) - B.P. 2966 (A20) - X-ray Lines 2.35, 2.03, 1.227 (A40)

Gold (I) chloride - AuCl - 232.7 - Yellow - D 7.8^{25} (B45) - D.T. 289.5 (I8)

Gold (III) chloride - $AuCl_3$ - 303.6 - Red - Needle-like - D 4.67^{25} (F21) - D.T. 254 (I8) - S.P. 265 (I8)

Gold (I) cyanide - AuCN - 223.2 - Light Yellow - D 7.122^{25} (B46) - X-ray Lines 2.94, 2.54, 5.1 (A40)

Gold (I) oxide - Au_2O - 410.4 - Dark Violet - D.T. 205 (I8)

Gold (III) oxide - Au_2O_3 - 442.4 - Brownish Black - D.T. 160 (I8)

Gold (III) selenide - Au_2Se_3 - 631.3 - Black - D 4.65 (I8)

Gold (III) sulfide - Au_2S_3 - 490.6 - Black - D 8.754 (I8) - D.T. 197 (I8)

Gold (II) telluride - AuTe (Calaverite) - 324.8 - Trigonal - D 9.04 (I8) - M.P. 464 (K79)

Gold telluride, di- - Au_2Te_4 (Nat. Krennerite) - 904.8 - Rhombic - D 9.31 (X-ray) (T55) - M.P. 472 (I8)

Hafnium - Hf - 178.6 - Hexagonal - D 11.4^{20} (A20) - M.P. 2230 (K79) - B.P. 5393 (A20) - X-ray Lines 2.72, 1.66, 1.42 (A41)

Hafnium chloride - $HfCl_4$ - 320.4 - M.P. 432 (F24) - S.P. 317 (F24)

Hafnium fluoride - HfF_4 - 254.6 - Monoclinic - D 7.13 (X-ray) (S27) - R.I. α 1.54, β 1.58, γ - (H55)

Hafnium oxide - HfO_2 - 210.6 - D 9.68 (I8) - M.P. 2810 (K79)

Hafnium phosphate - $HfO_2 \cdot P_2O_5$ - 352.6 - Colorless - Cubic - D 4.278 (L44)

Holmium - Ho - 164.94 - Hexagonal - D 8.76 (X-ray)(B93) - X-ray Lines 2.70 1.50, 1.78 (A41)

Holmium chloride - $HoCl_3$ - 271.31 - Yellow - D 4.25 (K37) - M.P. 718 (J16)

Holmium oxide - Ho_2O_3 - 377.88 - Pale Yellow - Cubic - D 8.36 (X-ray) (Z7)

Holmium sulfate, hydrate - $Ho_2(SO_4)_3 \cdot 8H_2O$ - 762.22 - Red - Monoclinic - D 3.149^{20} (H53)

Hydrogen - H (H_2) - 1.0080 (1.008123 for H^1 [D38]) - Colorless Gas - Hexagonal - D 0.0890^{-269} (Solid) (M24) - M.P. -259.4 (A20) - B.P. -252.7 (A20) - R.I. $1.112^{B.P.}$ (λ=5461) (J24)

Hydrogen, para- - H (Para-H_2) - 1.0080 - Colorless Gas - B.P. -252.82 (K13)

Hydrogen, heavy - HD - 3.022831 (Physical Scale) (B41a) - Colorless Gas - M.P. -256.5 (A19) (U2)

Hydrogen, heavy - D (D_2) - 2.014708 (Physical Scale) (B41a) - Colorless Gas - D 0.2059^{-269} (Solid) (M24) - M.P. -254.58 (K79) - B.P. -249.66 (K79)

Hydrogen chloride - HCl - 36.465 - Colorless Gas - D $1.194^{-85.8}$ (I8) - M.P. -114.19 (K15) - T.P. -174.2 (G41) - B.P. -85 (K13)

Hydrogen cyanide - HCN - 27.026 - Colorless Liquid - D 0.6950^{18} (F52) - M.P. -14.2 (L47) - B.P. 23.5 (L51)

Hydrogen fluoride - H_2F_2 - 40.02 - Colorless Liquid - D 1.0005^{0} (H62) - M.P. -83.7 (C1) - B.P. 19.54 (F51)

Hydrogen oxide - See Water

Hydrogen oxide, per- - H_2O_2 - 34.016 - Colorless Liquid - D 1.4649^{0} (R12) - M.P. -89 (R12) - B.P. 152.1 (R12) - R.I. 1.4087 (G32a)

Hydrogen selenide - H_2Se - 80.98 - Colorless Gas - D 1.961^{-27} (Liquid) (R36) - M.P. -65.74 (K101) - T.P. -100.63, -190.9 (K101) - B.P. -41.3 (K13)

Hydrogen sulfide - H_2S - 34.082 - Colorless Gas - D 0.9714^{-79} (Liquid) (K38); 1.217^{-195} (Solid) (B66) - M.P. -85.57 (K101) - T.P. -146.93, -169.60 (K101) - B.P. -60.3 (K13) - R.I. 1.374 (Liquid) (I8)

Hydrogen telluride - H_2Te - 129.63 - Colorless Gas - D $2.701^{-17.7}$ (Liquid) (R36) - M.P. -48.9 (K15) - B.P. 0.0 (K79)

Indium - In - 114.76 - Silvery - Tetragonal (A20) - D 7.275^{25} (H61) - M.P. 156.4 (A20) - B.P. 2000 (in N_2) (K63a) - X-ray Lines 2.70, 2.29, 1.675 (A40)

Indium (III) borate - $In_2O_3 \cdot B_2O_3$ - 347.16 - Colorless or Slight Yellow - Hexagonal - D 5.576 (X-ray) (G46) - R.I. $\omega, \varepsilon > 1.74$ (G46)

Indium (I) chloride - InCl (I) - 150.22 - Red - D 4.18^{25} (I and II) (K44) - M.P. 225 (K42) - B.P. 608 (R31)

Indium (I) chloride - InCl (II) - 150.22 - Yellow - D 4.19^{25} (K42) - Transition to I 120 (K42)

Indium (II) chloride - $InCl_2$ - 185.67 - Colorless - Rhombic - D 3.655^{25} (K44) - M.P. 235 (A6) - B.P. 570 (A6)

Indium (III) chloride - $InCl_3$ - 221.13 - D 3.45 (K44) - M.P. 586 (K42) - S.P. 498 (R31) - X-ray Lines 5.8, 2.55, 3.00 (A40)

Indium (III) fluoride - InF_3 - 171.76 - D 4.39 (H12) - M.P. 1170 (H12) - B.P. >1200 (H12)

Indium (III) hydroxide - $In(OH)_3$ - 165.78 - Yellow - Cubic - D 4.45 (F57) - D.T. 207 (F57) - $-H_2O$ at 150 (R12) - X-ray Lines 3.880, 1.061, 2.767 (P7)

Indium (I) oxide - In_2O - 245.52 - Black - D 6.99 (K55) - S.P. 675 (High Vacuum) (T23)

Indium (III) oxide - In_2O_3 - 277.52 - Yellow - Trigonal - D 7.04^{25} (K55) - M.P. ~ 2000 (K55)

Indium (I) selenide - In_2Se - 308.48 - Black - D 6.17^{25} (K55)

Indium (II) selenide - InSe - 193.72 - Black - D 5.55^{25} (K55) - M.P. 660 (K55)

Indium (III) selenide - In_2Se_3 - 466.40 - Black - D 5.67^{25} (K55) - M.P. 890 (K55)

Indium (III) sulfate - $In_2(SO_4)_3$ - 517.72 - Colorless - D 3.438 (I8) - D.T. 810 (760 m.m.) (S48)

Indium (I) sulfide - In_2S - 261.59 - Dark Brown - D 5.87^{25} (K55) - M.P. 653 (T23)

Indium (II) sulfide - InS - 146.83 - Red Brown - D 5.18 (K55) - M.P. 692 (K55)

Indium (III) sulfide - In_2S_3 - 325.72 - Black or Red - D 4.89 (K55) - M.P. 1050 (K55)

Indium (I) telluride - In_2Te - 357.13 - Black - D 6.47^{25} (K55)

Indium (II) telluride - InTe - 242.37 - Steel Blue - D 6.29^{25} (K55) - M.P. 696 (K55)

Indium (III) telluride - In_2Te_3 - 612.35 - Black - D 5.75^{25} (K55) - M.P. 667 (K55)

Iodine - I - 126.92 - Grayish Black - Rhombic - D 4.93^{20} (A20) - M.P. 114 (A20) - B.P. 184.5 (K79) - X-ray Lines 3.69, 3.09, 1.97 (A40)

Iodine (V) oxide - I_2O_5 - 333.84 - Colorless - D 4.80^{25} (B19) - X-ray Lines 3.28, 3.40, 3.79 (A40)

Iridium - Ir - 193.1 - White - Cubic - D 22.5^{20} (A20) - M.P. 2454 (A20) - B.P. 5300 (A20) - X-ray Lines 2.185 1.346, 1.150 (A40)

Iridium (II) chloride - $IrCl_2$ - 264.0 - Black Green - Hexagonal, Trigonal - D.T. 773 (I8)

Iridium (III) chloride - $IrCl_3$ - 299.47 - Olive Green - D 5.30 (R12) - D.T. 763 (R12) - X-ray Lines 5.7, 2.44, 1.73 (A40)

Iridium (VI) fluoride - IrF_6 - 307.1 - Pale Yellow - Tetragonal - D 6.0^{-190} (R73) - B.P. 53 (R73)

Iridium (VI) selenide - $IrSe_3$ - 430.0 - D 8.05 (B50)

Iron - Fe - 55.85 - Silver White - Cubic - D 7.87 (A20) - M.P. 1539 (R40) - T.P. 909.5 (W30) - B.P. 2740 (A20) - X-ray Lines 2.01, 1.166, 1.428 (A40)

Iron (II) aluminate - $FeO \cdot Al_2O_3$ (Hercynite) - 173.79 - Colorless - Cubic - D 4.35 (W45) - M.P. 1440 (Incong.) (M19) - R.I. 1.83 (W45)

Iron (II) aluminate - $3FeO \cdot Al_2O_3$ - 317.49 - M.P. 1225 (Incong.) (M19)

Iron (III) aluminate - $86Fe_2O_3 \cdot 14Al_2O_3$ - 15161.36 - X-ray Lines 2.67, 2.49, 1.82 (A41)

Iron (II) aluminum chromite - $FeO \cdot Al_2O_3 \cdot Cr_2O_3$ - 325.81 - X-ray Lines 2.48, 1.455, 1.58 (A40)

Iron (II) aluminum phosphate, hydrate - $FeO \cdot Al_2O_3 \cdot P_2O_5 \cdot 4H_2O$ (Nat. Metavauxite) - 387.814 - Colorless - Monoclinic - D 2.345 (G54) - R.I. α 1.550, β 1.561, γ 1.577 (G54) - X-ray Lines 2.75, 4.67, 4.32 (A41)

Iron (II) aluminum phosphate, hydrate - $FeO \cdot Al_2O_3 \cdot P_2O_5 \cdot 5H_2O$ (Nat. Paravauxite) - 405.83 - Colorless - Triclinic - D 2.358 (G54) - R.I. α 1.554, β 1.558, γ 1.573 (G54)

Iron (II) aluminum phosphate, hydrate - $FeO \cdot Al_2O_3 \cdot P_2O_5 \cdot 6H_2O$ (Nat. Vauxite) - 423.846 - Colorless - Triclinic - D 2.389 (G54) - R.I. α 1.551, β 1.555, γ 1.562 (G54)

Iron (II) aluminum silicate - $3FeO \cdot Al_2O_3 \cdot 3SiO_2$ (Nat. Almandite) - 497.67 - Cubic - D 4.04 (I8) - M.P. 1180 (Z34) - R.I. 1.830 (W42a) - X-ray Lines 2.58, 1.54, 1.07 (A41)

Iron (II) aluminum silicate, hydrate - $FeO \cdot Al_2O_3 \cdot SiO_2 \cdot H_2O$ (Nat. Chloritoid) - 251.87 - Brilliant Dark Green - Monoclinic, Flakes - R.I. α 1.720, β 1.722, γ 1.731 (L12)

Iron (II) antimonate - $2FeO \cdot Sb_2O_5$ (Nat. Tripuhyite) - 467.22 - Greenish Yellow - D 5.82 (I8) - R.I. α 2.19, β 2.20, γ 2.33 (I8)

Iron (II) antimony (III) sulfide - $FeS \cdot Sb_2S_3$ (Berthierite) - 427.63 - X-ray Lines 2.60, 3.62, 3.15 (A41)

Iron (III) arsenate - $Fe_2O_3 \cdot As_2O_5$ - 389.52 - Brown - Monoclinic - D 4.32 (W42) - R.I. α -, β 1.78, γ - (W42)

Iron (III) arsenic (V) sulfide - $Fe_2S_3 \cdot As_2S_5$ (Nat. Arsenopyrite) - 357.72 - X-ray Lines 2.65, 2.42, 1.81 (A41)

Iron (II) carbonate - $FeCO_3$ (Siderite) - 115.86 - Brown - Trigonal - D 3.832 (B49) - D.T. 282 (1 atm. CO_2) (K79) - R.I. ω 1.875, ϵ 1.633 (I8) - X-ray Lines 2.78, 1.73, 3.58 (A41)

Iron (II) chloride - $FeCl_2$ (Lawrencite) - 126.76 - Green - Hexagonal - D 3.162 (B53) - M.P. 677 (K15) - B.P. 1026 (K13) - R.I. ω 1.57, ϵ - (I8) - X-ray Lines 2.54, 5.8, 1.796 (A40)

Iron (III) chloride - Fe_2Cl_6 (Molysite) - 324.44 - Brownish Yellow - Hexagonal - D 2.904^{17} (H91) - M.P. 300 (K79) - B.P. 307 (K79) - X-ray Lines 2.68, 2.08, 5.9 (A40)

Iron (III) chloride, oxy- - $FeOCl$ - 107.31 - Rhombic - D 3.53 (X-ray) (S119) - X-ray Lines 8.2, 3.42, 2.53 (A40)

Iron (II) chromate - $FeO \cdot Cr_2O_3$ (Chromite) - 223.87 - Black - Cubic - D 5.08 (W45) - M.P. 1670 (K79) - R.I. 2.16 (I8) - X-ray Lines 2.02, 2.82, 3.10 (A41)

Iron (III) chromite - $Fe_2O_3 \cdot Cr_2O_3$ - 311.72 - X-ray Lines 1.68, 3.67, 2.68 (A41)

Iron (III) chromite - $Fe_2O_3 \cdot 3Cr_2O_3$ - 615.76 - X-ray Lines 1.67, 3.64, 2.67 (A41)

Iron (III) chromite - $3Fe_2O_3 \cdot Cr_2O_3$ - 631.12 - X-ray Lines 1.68, 3.69, 2.68 (A41)

Iron (II) chromium (III) sulfide - $FeS \cdot Cr_2S_3$ (Daubreelite) - 288.13 - X-ray Lines 3.02, 1.77, 2.50 (A41)

Iron (II) columbate - $FeO \cdot Cb_2O_5$ (Nat. Ferroniobite) - 337.67 - Rhombic - D 6.26 (I8) - R.I. α -, β 2.40 (Li-Line), γ - (I8)

Iron (III) columbate - $Fe_2O_3 \cdot Cb_2O_5$ (Columbit) - 425.52 - Orthorhombic - R.I. α -, β 2.40, γ - (L12)

Iron (II) fluoride - FeF_2 - 93.85 - Colorless - Tetragonal - D 3.95 (R69) - M.P. > 1000 (B69)

Iron (III) fluoride - FeF_3 - 112.85 - Greenish - Triclinic - D 3.52 (R69) - X-ray Lines 3.74, 1.87, 1.69 (A41)

Iron (II) fluoride, hydrate - $FeF_2 \cdot 4H_2O$ - 165.91 - D 2.095^{25} (B69) - X-ray Lines 5.5, 3.91, 3.48 (A40)

Iron (III) fluoride, hydrate - $FeF_3 \cdot 3H_2O$ - 166.90 - Tetragonal - D 2.26 (N25) - R.I. ω 1.489, ε 1.454 (N25)

Iron (III) fluoride, hydrate - $FeF_3 \cdot 3H_2O$ - 166.90 - Rhombohedral - D 2.20 (N25) - R.I. ω 1.452, ε 1.485 (N25)

Iron (II) manganese (IV) oxide - $FeO \cdot MnO_2$ (Bixbyite) - 158.78 - Black, Metallic, Opaque - Cubic - D 4.95 (I8)

Iron (III) nitrate, hydrate - $Fe(NO_3)_3 \cdot 6H_2O$ - 349.97 - Colorless - Cubic - M.P. 35 (I8)

Iron (III) nitrate, hydrate - $Fe(NO_3)_3 \cdot 9H_2O$ - 404.02 - X-ray Lines 6.6, 4.10, 2.62 (A40)

Iron (II) oxide - FeO (Wuestite) - 71.85 - Greyish Blue - Cubic - D 5.745^{28} (R50) - M.P. 1370 (Incong.) (K79) - R.I. 2.32 (B114) - X-ray Lines 2.14, 1.51, 0.956 (A41)

Iron (II, III) oxide - Fe_3O_4 (Magnetite) - 231.55 - Reddish Black - Cubic - D 5.125^{18} (L11) - M.P. 1590 (H90) - T.P. 510-680 (K79) - R.I. 2.42 (L57) - X-ray Lines 2.54, 1.48, 1.61 (A41)

Iron (III) oxide - Fe_2O_3 (Hematite) - 159.70 - Red - Hexagonal - D 5.200^{18} (R63) - M.P. 1545 (Incong.) (K59) - T.P. 678 (S81), 1030 (E17) - R.I. ω 3.01, ε 2.78 (M41) - X-ray Lines 2.69, 2.51, 1.69 (A41)

Iron (III) oxide - Fe_2O_3 ('γ') - 159.70 - D 4.59 (H5) - X-ray Lines 2.51, 1.48, 1.60 (A41)

Iron (III) oxide - Fe_2O_3 ('δ') - 159.70 - D 4.7 (G38) - X-ray Lines 2.19, 1.69, 2.53 (A41)

Iron (III) oxide, hydroxy- - $FeO(OH)$ (Goethite) - 88.86 - Red - Rhombic - D 4.28 (I8) - D.T. 300 (K79) - -½H_2O at 136 (W32a) - R.I. α 2.260, β 2.394, γ 2.400 (P61) - X-ray Lines 4.18, 2.45, 2.69 (A41)

Iron (III) oxide, hydroxy- - $FeO(OH)$ (Nat. Lepidocrocite) - 88.86 - Red - Rhombic - D 4.09 (I8) - D.T. 300-400 (G49) - -½H_2O at 240 (K79) - R.I. α 1.94, β 2.20, γ 2.51 (I8) - X-ray Lines 3.33, 2.55, 7.4 (A40)

Iron (II) oxide, hydrate - $FeO \cdot H_2O$ - 89.87 - Greenish White - D 3.40 (N6)

Iron (II) phosphate, ortho- - $3FeO \cdot P_2O_5$ (I) - 357.51 - Colorless - M.P. 1238 (W36)

Iron (II) phosphate, ortho- - $3FeO \cdot P_2O_5$ (II) - 357.51 - Gray - Transition to I 942 (W36)

Iron (III) phosphate, ortho- - $Fe_2O_3 \cdot P_2O_5$ (I) - 301.66 - Dark Gray - Tabular Prism - M.P. 1240 (W36)

Iron (III) phosphate, ortho- - $Fe_2O_3 \cdot P_2O_5$ (II) - 301.66 - Gray - Transition to I 889 (W36)

Iron (III) phosphate, ortho- - $Fe_2O_3 \cdot P_2O_5$ (III) - 301.66 - Colorless-Needle - D 3.1 (C2) - Transition to II 789 (W36)

Iron (III) phosphate, meta- - $Fe_2O_3 \cdot 3P_2O_5$ - 585.58 - Colorless - Rhombic - D 3.02 (I8)

Iron (III) phosphate - $2Fe_2O_3 \cdot 3P_2O_5$ (I) - 745.28 - M.P. 1270 (W36)

Iron (III) phosphate - $2Fe_2O_3 \cdot 3P_2O_5$ (II) - 745.28 - Transition to I 865 (W36)

Iron (II) phosphate, hydrate - $3FeO \cdot P_2O_5 \cdot 8H_2O$ (Nat. Vivianite) - 501.64 - Chestnut Brown - Monoclinic - D 3.84 (M13) - R.I. α 1.673, β 1.681, γ 1.691 (M13)

Iron (II) phosphate, hydrate - $7FeO \cdot 2P_2O_5 \cdot 9H_2O$ (Nat. Ludlamite) - 949.01 - Monoclinic - D 3.72 (I8) - R.I. α 1.653, β 1.675, γ 1.697 (L18)

Iron (III) phosphate, hydrate - $Fe_2O_3 \cdot P_2O_5 \cdot 4H_2O$ (Nat. Strengite) - 373.72 - Rhombic - D 2.87 (I8) - R.I. α 1.708, β 1.708, γ 1.745 (L18) - X-ray Lines 4.36, 5.5, 3.12 (A41)

Iron (III) phosphate, hydrate - $Fe_2O_3 \cdot P_2O_5$ $6H_2O$ (Nat.Koninchite) - 409.76 - Rhombic - D 2-3 (L18) - R.I. α -, β 1.58, γ - (L18)

Iron (III) phosphate, hydrate - $Fe_2O_3 \cdot 2SiO_2 \cdot 7H_2O$ (Nat. Nemecite) - 405.93 - Cubic - D 2.075 (K5) - R.I. 1.608 (K5)

Iron (III) phosphate, hydrate - $2Fe_2O_3 \cdot P_2O_5 \cdot 3H_2O$ (Nat. Dufrenite) - 515.41 - Dull Leak Green - Monoclinic - D 3.3 (L18) - R.I. α 1.830, β 1.840, γ 1.885 (I8)

Iron (III) phosphate, hydrate - $2Fe_2O_3 \cdot P_2O_5 \cdot 12H_2O$ (Nat. Cacoxenite) - 677.55 - Hexagonal - D 3.38 (I8) - R.I. ω 1.582, ϵ 1.645 (I8)

Iron (III) phosphate, hydrate - $2Fe_2O_3 \cdot 2P_2O_5 \cdot 7H_2O$ (Nat. Phosphosiderite) - 729.43 - Rhombic - D 2.724 (L18) - R.I. α 1.692, β 1.725, γ 1.738 (L18)

Iron (III) phosphate, hydrate - $3Fe_2O_3 \cdot 2P_2O_5 \cdot 8H_2O$ (Nat. Beraunite) - 907.15 - Monoclinic - D 2.9 (I8) - R.I. α 1.775, β 1.786, γ 1.815 (I8)

Iron (III) phosphate, hydrate - $3Fe_2O_3 \cdot 2P_2O_5 \cdot 10H_2O$ - 943.18 - White - Rhombic - D 2.82 (S105) - R.I. 1.745 (mean) (S105) - X-ray Lines 3.91, 3.28, 3.01 (S105)

Iron (II) selenide - $FeSe$ - 134.81 - Dark Gray - Tetragonal, hexagonal, Monoclinic - D 6.78 (X-ray) (Y4)

Iron (III) selenide - Fe_2Se_3 - 348.58 - Grayish Yellow - D 6.38 (L53)

Iron (II) silicate, meta- - $FeO \cdot SiO_2$ (Gruenerite) - 131.91 - Grayish Green - Monoclinic - D 3.44 (S95) - M.P. 1146 (W29) - R.I. α 1.672, β 1.697, γ 1.717 (I8)

Iron (II) silicate, ortho- - $2FeO \cdot SiO_2$ (Fayalite) - 203.76 - Greenish Brown - Rhombic - D 4.241^{20} (R54) - M.P. 1205 (B114) - R.I. α 1.824, β 1.864, γ 1.875 (B114) - X-ray Lines 2.85, 1.76, 3.71 (A41)

Iron (II) silicate, fluo-, hydrate - $FeF_2 \cdot SiF_4 \cdot 6H_2O$ - 306.01 - Bluish Green - Trigonal - R.I. ω 1.3638 ε 1.3848 (I8)

Iron (II) silicate, fluoride - $6FeO \cdot 8SiO_2 \cdot FeF_2$ - 1005.43 - R.I. α 1.665, β 1.676, γ 1.690 (B113)

Iron (II) silicate, hydrate - $3FeO \cdot 4SiO_2 \cdot 2H_2O$ (Nat. Greenalite) - 491.82 - Green - Cubic - D 3.0 (J31) - R.I. 1.675 (J31)

Iron (II) silicate, hydrate - $7FeO \cdot 8SiO_2 \cdot H_2O$ (Nat. Gruenerite) - 1001.45 - Greenish Gray - D 3.597 (B113) - R.I. α 1.686, β 1,709, γ 1.729 (B113)

Iron (II, III) silicate, hydrate - $2FeO \cdot Fe_2O_3 \cdot SiO_2 \cdot 2H_2O$ (Nat. Cionstedlite) - 399.49 - Monoclinic (pseudohexogonal) - R.I. α-, β 1.721, γ 1.721 (L12)

Iron (II, III) silicate, hydrate - $9FeO \cdot Fe_2O_3 \cdot 8SiO_2 \cdot 8H_2O$ (Nat. Greenite) - 1430.96 - R.I. $\sim$ 1.670 (G80) - X-ray Lines 2.57, 7.12, 3.56 (A41)

Iron (III) silicate, hydrate - $Fe_2O_3 \cdot 2SiO_2 \cdot 2H_2O$ (Nat. Nontromite) - 315.85 - Monoclinic - R.I. α 1.56-1.595, β 1.585-1.604, γ 1.575-1.620 (L11)

Iron (III) silicate, hydrate - $Fe_2O_3 \cdot 2SiO_2 \cdot 4H_2O$ (Nat. Canbyite) - 351.88 - Amber Brown - R.I. α 1.562, β 1.580, γ 1.582 (L18)

Iron (III) silicate, hydrate - $Fe_2O_3 \cdot 4SiO_2 \cdot H_2O$ (Nat. Nontronite) - 417.96 - X-ray Lines 15.6, 4.55, 1.52 (A41)

Iron (III) silicate, hydrate - $2Fe_2O_3 \cdot 2SiO_2 \cdot 3H_2O$ (Nat. Iddingsite) - 493.57 - Rhombic - D 2.8 (I8) - R.I. α 1.71, β 1.74, γ 1.76 (I8)

Iron (III) silicate, hydrate - $2Fe_2O_3 \cdot 3SiO_2 \cdot 18H_2O$ (Copiapite) - 823.87 - Monoclinic - R.I. α 1.509, β 1.532, γ 1.577 (L10)

Iron (II) sulfate - $FeSO_4$ - 151.92 - Colorless - D 3.346 (T28) - D.T. 665 (1 atm.) (K79) - X-ray Lines 3.25, 4.78, 1.99 (A40)

Iron (III) sulfate - $Fe_2(SO_4)_3$ - 399.90 - Light Yellowish Rose - Rhombic - D 3.02 (K24) - B.F. 707 (715 m.m.) (W52) - R.I. α 1.802, β 1.814, γ 1.818 (P62)

Iron (III) sulfate - $Fe_2(SO_4)_3$ - 399.90 - Yellow - Hexagonal - D 3.23 (K64) - R.I. ω 1.770, ε 1.760 (P62)

Iron (II) sulfate, hydrate - $FeSO_4 \cdot H_2O$ (Szomolnikite) - 169.93 - Monoclinic - D 2.970^{28} (M58) - X-ray Lines 3.42, 4.85, 3.13 (A40)

Iron (II) sulfate, hydrate - $FeSO_4 \cdot 4H_2O$ - 223.98 - Greenish White - Monoclinic - D 2.293^{28} (M58) - R.I. α 1.533, β 1.535, γ- (L12) - X-ray Lines 5.5, 4.49, 3.99 (A40)

Iron (II) sulfate, hydrate - $FeSO_4 \cdot 5H_2O$ (Nat. Siderotil) - 242.00 - Greenish White - Triclinic - D 2.2 (I8) - R.I. α 1.528, β 1.537, γ 1.543 (I8)

Iron (II) sulfate, hydrate - $FeSO_4 \cdot 7H_2O$ (Melanterite)-278.03 - Greenish White - Monoclinic - D 1.895^{28}(M58) - $-3H_2O$ at 56.7; $-6H_2O$ at 100; $-7H_2O$ at 300 (K79) - R.I. α 1.4713, β 1.4782, γ 1.4856 (I8) - X-ray Lines 4.90, 3.78, 3.23 (Form not defined) (A40)

Iron (II) sulfate, hydrate - $FeSO_4 \cdot 7H_2O$ (Tauriseite) - 278.03 - Rhombic - D 1.875 (R19)

Iron (III) sulfate, hydrate - $Fe_2(SO_4)_3 \cdot 4H_2O$ - 471.96 - R.I. α -, β 1.533, γ 1.535 (L11)

Iron (III) sulfate, hydrate - $Fe_2(SO_4)_3 \cdot 6H_2O$ - 507.99 - Colorless - Monoclinic - R.I. α 1.605, β 1.635, γ 1.657 (P62)

Iron (III) sulfate, hydrate - $Fe_2(SO_4)_3 \cdot 7H_2O$ - 526.01 - Colorless to Pink - Monoclinic - R.I. α 1.572, β 1.586, γ 1.640 (P62)

Iron (III) sulfate, hydrate - $Fe_2(SO_4)_3 \cdot 9H_2O$ - 562.04 - Yellow - Hexagonal - D 2.1 (I8) - Transition to lower hydrates 85, 93, 161 (K79) - R.I. ω 1.552, ε 1.558 (I8)

Iron (II) sulfide - FeS (I) (Troilite) - 87.92 - Rhombic - D 4.787 (G41) - M.P. (in H_2S) 1175; (in 1 atm. S vapor) 1187 (K79) - X-ray Lines 2.06, 2.97, 2.65 (Form not defined) (A40)

Iron (II) sulfide - FeS (II) (Magnetkies) - 87.92 - Dark Brown - Hexagonal - D 4.764^{25} (J42) - Transition to I 140 (K79)

Iron (III) sulfide - Fe_2S_3 - 207.90 - Grayish Yellow - D 4.3 (I8)

Iron sulfide - FeS_2 (Artificial Pyrite) - 119.98 - D 5.01 (J42) - D.T. 440 (K17)

Iron sulfide - FeS_2 (Pyrite) - 119.98 - Yellow - Cubic - D 4.911(A10) X-ray Lines 1.64, 2.76, 2.46 (A41)

Iron sulfide - FeS_2 (Nat. Marcasite) - 119.98 - Rhombic - D 4.5-4.9 (G41) - Transition to Pyrite 415 (K79) - D.T. 690 (1 atm. S vapor) (K79) - X-ray Lines 2.68, 1.90, 1.75 (A41)

Iron (II) tantanlate - $FeO \cdot Ta_2O_5$ (Nat. Tapiolite) - 513.61 - Light Brown - Tetragonal - D 7.33 (C17) - R.I. ω ∼ 2.27, ε ∼ 2.42 (Li-Line) (L18)

Iron telluride - $FeTe_2$ (Frohbergite) - 311.07 - Rhombic - D 7.98 (X-ray) (T27a)

Iron (III) tellurite - $Fe_2O_3 \cdot 3TeO_2$ - 644.53 - X-ray Lines 1.71, 3.27, 2.54 (F72)

Iron (II) titanate - $FeO \cdot TiO_2$ (Ilmenite) - 151.75 - Black - Trigonal-D 4.75 (I8) - M.P. 1470 (G68) - T.P. 215 (K61); 1367 (N15) - X-ray Lines 2.73, 2.53, 1.72 (A41)

Iron (II) titanate - $2FeO \cdot TiO_2$ (Pseudobrookite) - 223.60 - Red - Rhombic - D 4.37 (H28) - M.F. 1470 (G68)

Iron (III) titanate - $Fe_2O_3 \cdot 3TiO_2$ (Nat. Arizonite) - 399.40 - Monoclinic - D 4.25 (I8) - R.I. α -, β 2.62, γ - (I8)

Iron (III) titanate - $2Fe_2O_3 \cdot 3TiO_2$ (Nat. Pseudobrookite) - 559.10 - Rhombic - D 4.7 (I8) - R.I. α 2.38, β 2.39, γ 2.42 (I8)

Iron (II) titanite - $FeO \cdot Ti_2O_3$ - 215.65 - Black - D 4.346^{21} (K92) - X-ray Lines 1.53, 2.44, 1.95 (A41)

Iron (II) tungstate - $FeO \cdot WO_3$ (Nat. Ferberite) - 303.77 - Tetragonal-D 6.64 (I8) - R.I. α -, β 2.40 (Li-Line), γ - (I8) - X-ray Lines 2.94, 4.71, 1.71 (A41)

Iron (III) tungstate, hydrate - $Fe_2O_3 \cdot WO_3 \cdot 6H_2O$ (Ferritungstite) - 499.72 - Hexagonal - R.I. ω 1.80, ε 1.72 (I8)

Lanthanum - La - 138.92 - White - Hexagonal or Cubic (T51) - D 6.15^{20} (A20) - M.P. 826 (A20) - B.P. 1800 (A20) - X-ray Lines 3.23, 2.86, 2.27 (A40); 3.04, 1.60, 2.86 (A41)

Lanthanum borate - $La_2O_3 \cdot B_2O_3$ - 395.48 - Colorless - Rhombic - D 5.339 (X-ray) (G46)

Lanthanum chloride - $LaCl_3$ - 245.29 - Colorless - Needle, Hexagonal - D 3.82 (K37) - M.P. 872 (K37) - B.P. > 1000 (V13)

Lanthanum chromite - $La_2O_3 \cdot Cr_2O_3$ - 477.86 - Blue Green - D 6.79 (N4)

Lanthanum fluoride - LaF_3 - 195.92 - Colorless - Cubic - D 4.49^{16} (B24) - R.I. 1.574 (S116)

Lanthanum germanate - $La_2O_3 \cdot GeO_2$ - 430.44 - Rhombic (G35)

Lanthanum hydroxide - La $(OH)_3$ - 189.94 - White - Hexagonal - D 4.78 (X-ray) (F57)

Lanthanum iron (III) oxide - $La_2O_3 \cdot Fe_2O_3$ - 485.54 - Brown - D 6.85 (N4)

Lanthanum manganese (III) oxide - $La_2O_3 \cdot Mn_2O_3$ - 483.70 - Black - D 6.87 (N4)

Lanthanum molybdate - $La_2O_3 \cdot MoO_3$ - 469.79 - Tetragonal - D 5.52 (S58)

Lanthanum molybdate - $La_2O_3 \cdot 3MoO_3$ - 757.69 - Tetragonal - D 4.77^{18} (I8) - M.P. 1181 (I8)

Lanthanum nitrate, hydrate - La $(NO_3)_3 \cdot 6H_2O$ - 433.04 - Colorless - Triclinic - M.P. 66.5 (Q3) - T.P. 43 (F66)

Lanthanum oxide - La_2O_3 - 325.84 - Colorless - Trigonal - D 6.51 (I8) - M.P. 2315 (W18) - B.P.~4200 (M88) - X-ray Lines 2.97, 3.41, 1.96 (A41)

Lanthanum phosphate - $La_2O_3 \cdot P_2O_5$ (I) - 467.80 - Colorless - Monoclinic - D 5.087 (X-ray) (M67)

Lanthanum phosphate - $La_2O_3 \cdot P_2O_5$ (II) - 467.80 - Colorless - Hexagonal - D 4.122 (X-ray) (M67)

Lanthanum phosphate - $La_2O_3 \cdot 5P_2O_5$ - 1035.64 - Monoclinic - D 3.241 (I8)

Lanthanum selenite - $La_2O_3 \cdot SeO_2$ - 436.80 - X-ray Lines 3.88, 2.90, 2.65 (P50)

Lanthanum selenide - La_2Se_3 - 514.72 - Brick Red - D 6.1 (K48)

Lanthanum selenide - La_2Se_4 - 593.68 - D 6.32 (K48)

Lanthanum silicate - $La_2O_3 \cdot SiO_2$ - 385.90 - Colorless - Hexagonal(G34)

Lanthanum silicate - $La_2O_3 \cdot 2SiO_2$ - 445.96 - Colorless - Tetragonal, Monoclinic - Melts Incong.

Lanthanum sulfate - $La_2(SO_4)_3$ - 566.04 - Colorless - D 3.600 (I8) - D.T. 1120 (430 m.m.) (P13) - X-ray Lines 4.90, 2.83, 2.88 (P50)

Lanthanum sulfate, hydrate - $La_2(SO_4)_3 \cdot 9H_2O$ - 728.18 - Colorless - Hexagonal - D 2.821 (I8) - R.I. ω 1.564, ε 1.569 (Red) (L9)

Lanthanum sulfate - La_2O_3 SO_3 - 405.91 - X-ray Lines 3.10, 1.70, 1.81, (P50)

Lanthanum sulfide - La_2S_3 - 374.04 - Cubic - D 5.01 (X-ray) (Z21) - M.P. 2100-2150 (In Vacuum) (R12)

Lanthanum sulfide - La_2S_3 - 374.04 - Yellow - Hexagonal - D 4.86^{25} (K49) - M.P. 2125 (In Vacuum) (P46) - X-ray Lines 3.55, 2.64, 2.56 (P50)

Lanthanum sulfide - La_2S_4 - 406.10 - D 4.76^{25} (K49) - D.T. 650 (I8)

Lanthanum sulfide oxide - La_2O_2S - 341.91 - Hexagonal - D 5.81 (X-ray) (Z22) - X-ray Lines 3.10, 3.48, 2.40 (P50)

Lead - Pb - 207.21 - Bluish White - Cubic - D 11.34 (A20) - M.P. 327.4 (A20) - T.P. 160 (K79) - B.P. 1740 (A20) - X-ray Lines 2.82, 1.48, 2.44 (A41)

Lead (II) aluminate - $PbO \cdot Al_2O_3$ - 325.15 - Unstable above 970 (G16) - R.I. ω 1.91, ε 1.85 (G16) - X-ray Lines 3.08, 4.43, 2.221 (G16)

Lead (II) aluminate, thio- - $PbS\cdot Al_2S_3$ - 389.41 - Rose Yellow - D 4.431^{28} (M61) - M.P. 860 (M61)

Lead (II) aluminate, thio- - $2PbS\cdot Al_2S_3$ - 628.69 - Dark Yellow - D 5.886^{25} (M61) - M.P. 751 (M61)

Lead (II) aluminum antimonate - $2PbO\cdot Al_2O_3\cdot Sb_2O_5$ - 871.88 - Light Yellow - D 7.2 (S112)

Lead (II) aluminum phosphate, hydrate - $2PbO\cdot 3Al_2O_3\cdot 2P_2O_5\cdot 7H_2O$ (Plumboguminite) - 1162.27 - Hexagonal - D 4.014 (I8) - R.I. ω 1.654, ε 1.676 (I8); ω 1.653, ε 1.675 (L11)

Lead (II) aluminum silicate - $4PbO\cdot Al_2O_3\cdot 2SiO_2$ - 1114.90 - M.P. 837 (Incong.) (G16) - R.I. ω 1.93, ε 1.94 (G16) - X-ray Lines 3.22, 2.76, 2.12 (G16)

Lead (II) aluminum silicate - $6PbO\cdot Al_2O_3\cdot 6SiO_2$ - 1801.56 - M.P. 811 (G16) - R.I. α 1.79 γ 1.89 (G16) - X-ray Lines 3.55, 2.75, 3.30, 2.070 (G16)

Lead (II) aluminum silicate - $8PbO\cdot Al_2O_3\cdot 4SiO_2$ - 2127.86 - M.P. 735 (Incong.) (G16) - R.I. α 2.04, γ 2.08 (G16) - X-ray Lines 3.26, 1.886, 1.735 (G16)

Lead (II) antimonate, meta- - $PbO\cdot Sb_2O_5$ - 546.73 - Colorless - D 6.8 (S112)

Lead (II) antimonate, pyro- - $2PbO\cdot Sb_2O_5$ - 769.94 - Yellow - Cubic - D 8.0 (S112) - X-ray Lines 1.61, 1.89, 1.09 (A41)

Lead (II) antimonate, ortho- - $3PbO\cdot Sb_2O_5$ (Nat. Monimolite) - 993.15- Dark Orange Yellow - D 6.58 (I8) - X-ray Lines 3.48, 2.65, 5.8 (A40)

Lead (II) antimonite - $PbO\cdot Sb_2O_3$ - 514.73 - M.P. 558 (M6)

Lead (II) antimony (III) sulfide - $PbS\cdot Sb_2S_3$ (Nat. Zinkenite) - 578.99 - Rhombic - D 5.36 (N41) - M.P. 525 (Incong.) (K79) - S.P. 475 (I8) - X-ray Lines 3.45, 1.98, 1.82 (A41)

Lead (II) antimony (III) sulfide - $2PbS\cdot Sb_2S_3$ (Jamesonite) - 818.27 - X-ray Lines 3.45, 2.06, 2.02 (A41)

Lead (II) antimony (III) sulfide - $2PbS\cdot Sb_2S_3$ (Nat. Plumosite) - 818.27 - Monoclinic - D 5.62 (I8) - M.P. 610 (Incong.) (K79)

Lead (II) antimony (III) sulfide - $2PbS\cdot 3Sb_2S_3$ (Rezbanyite) - 1497.71 X-ray Lines 3.22, 3.01, 3.60 (A41)

Lead (II) antimony (III) sulfide - $3PbS\cdot Sb_2S_3$ - 1057.55 - Gray - Rhombic, Monoclinic - D 6.17 (I14)

Lead (II) antimony (III) sulfide - $3PbS\cdot 4Sb_2S_3$ (Nat. Fülöppite) - 2076.71 - Monoclinic (N40) - X-ray Lines 3.23, 3.82, 3.38 (A41)

Lead (II) antimony (III) sulfide - $4PbS\cdot Sb_2S_3$ (Nat. Meneghinite) - 1296.83 - X-ray Lines 2.91, 3.25, 2.07 (A41)

Lead (II) antimony (III) sulfide - $5PbS\cdot Sb_2S_3$ (Geocronite) - 1536.10- X-ray Lines 2.24, 1.83, 3.19 (A41)

Lead (II) antimony (III) sulfide - $5PbS\cdot 2Sb_2S_3$ (Nat. Boulangerite) - 1875.82 - Monoclinic - D 6.23 (B40) - X-ray Lines 2.80, 3.70, 1.86 (A41)

Lead (II) antimony (III) sulfide - $5PbS\cdot 4Sb_2S_3$ (Nat. Plagionite) - 2555.26 - Monoclinic - D 5.54 (N41) - M.P. 570 (Incong.) (K79) - X-ray Lines 3.52, 3.23, 2.93 (A41)

Lead (II) antimony (III) sulfide - $9PbS\cdot 4Sb_2S_3$ (Nat. Semseyite) - 3512.38 - Monoclinic - D 6.03 (N41) - X-ray Lines 3.20, 2.97, 3.77 (A41)

Lead (II) antimony (III) sulfide - $11PbS\cdot6Sb_2S_3$ (Heteromorphite) - 4670.38 - X-ray Lines 3.42, 1.89, 2.87 (A41)

Lead (II) arsenate, meta- - $PbO\cdot AS_2O_5$ - 453.03 - Hexagonal - D 6.42 (I8)

Lead (II) arsenate, pyro- - $2PbO\cdot AS_2O_5$ - 676.24 - Rhombic - D 6.85 (I8) - M.P. 802 (I8) - R.I. α -,β 2.03, γ - (I8)

Lead (II) arsenate, ortho- - $3PbO\cdot AS_2O_5$ - 899.45 - Yellow White - D 7.30 (I8) - M.P. 1042 (I8) - R.I. 2.14 (M29)

Lead (II) arsenate -$4PbO\cdot As_2O_5$ - 1122.66 - M.P. 834 (Incong.) (K79)

Lead (II) arsenate - $8PbO\cdot As_2O_5$ - 2015.50 - M.P. 862 (I8)

Lead (II) arsenate, hydrate - $PbO\cdot As_2O_5\cdot 2H_2O$ - 489.06 - Triclinic - D 4.46 (I8) - D.T. 140 (I8) - R.I. α 1.74, β 1.82, γ - (I8)

Lead (II) arsenate, hydrate - $2PbO\cdot As_2O_5\cdot H_2O$ (Nat. Schultenite) - 694.26 - Colorless - Monoclinic - D 5.79 (I8) - M.P. >200 (I8) - R.I. α 1.90, β 1.91, γ 1.97 (I8) - X-ray Lines 3.39, 3.17, 2.93 (A40)

Lead (II) arsenate, hydrate - $6PbO\cdot 2As_2O_5\cdot H_2O$ - 1816.92 - D 7.00(I8)

Lead (II) arsenite - $PbO\cdot As_2O_3$ - 421.03 - White - D 5.85 (I8)

Lead (II) arsenic (III) sulfide - $PbS\cdot As_2S_3$ (Nat. Sartorite) - 485.29 - Rhombic - D 4.6 (I8) - D.T. <700 (I8) - X-ray Lines 3.48, 2.95, 2.76 (A41)

Lead (II) arsenic (III) sulfide - $2PbS\cdot As_2S_3$ (Nat. Dufrenoysite) - 724.57 - Rhombic - D 5.50 (I8) - M.P. 580 (Incong.) (K79) - X-ray Lines 3.01, 2.84, 2.09 (A41)

Lead (II) arsenic (III) sulfide - $3PbS\cdot 2As_2S_3$ (Nat. Baumhauerite) - 1209.86 - Monoclinic - D 5.43 (X-ray) (P28) - X-ray Lines 2.73, 2.30, 2.11 (A41)

Lead (II) arsenic (III) sulfide - $3PbS\cdot As_2S_3$ (Guitermanite) - 963.85- X-ray Lines 3.18, 2.22, 1.82 (A41)

Lead (II) arsenic (III) sulfide - $3PbS\cdot 2As_2S_3$ (Rathite) - 1209.86 - X-ray Lines 2.96, 2.72, 2.32 (A41)

Lead (II) arsenic (III) sulfide - $4PbS\cdot As_2S_3$ (Jordanite) - 1203.13 - X-ray Lines 2.22, 2.10, 1.82 (A41)

Lead (II) arsenic (III) sulfide - $9PbS\cdot 2As_2S_3$ (Gratonite) - 2645.54 - X-ray Lines 3.80, 3.47. 2.94 (A41)

Lead (II) bismuth (III) carbonate - $6PbO\cdot Bi_2O_3\cdot 3CO_2$ (Boksputite) - 1937.29 - Yellow - D 7.29^{28} (M90)

Lead (II) bismuth (III) oxide - $PbO\cdot 2Bi_2O_3$ - 1155.21 - M.P. 690 (Incong.) (K79)

Lead (II) bismuth (III) oxide - $2PbO\cdot Bi_2O_3$ - 912.42 - M.P. 625 (B31)

Lead (II) bismuth (III) oxide - $2PbO\cdot 3Bi_2O_3$ - 1844.42 - M.P. 686(B31)

Lead (II) bismuth (III) sulfide - $PbS\cdot Bi_2S_3$ (Galenobismutite) - 753.48 - D 6.9 (I8)

Lead (II) bismuth (III) sulfide - $PbS\cdot 2Bi_2S_3$ (Cannizarite) - 1267.68- X-ray lines 3.80, 3.00, 2.03 (A41)

Lead (II) bismuth (III) sulfide - $2PbS\cdot Bi_2S_3$ (Cosalite) - 992.76 - X-ray Lines 2.95, 3.40, 2.02 (A41)

Lead (II) borate - $PbO\cdot 2B_2O_3$ - 362.49 - M.P. 768 (G14) - R.I. α 1.915 β-, γ 1.935 (G14)

Lead (II) borate - $2PbO\cdot B_2O_3$ (I) - 516.06 - M.P. 497 (Incong.) (G14)- R.I. α 1.965, β-, γ 2.025 (G14)

Lead (II) borate - $2PbO\cdot B_2O_3$ (II) - 516.06 - Transition to I 473 (G14) - R.I. α 2.08, β 2.10, γ 2.11 (G14)

Lead (II) borate - $4PbO\cdot B_2O_3$ (I) - 962.48 - M.P. 565 (G14) - R.I. α 2.15, β -, γ 2.20 (G14)

Lead (II) borate - $4PbO\cdot B_2O_3$ (II) - 962.48 - T.P. 552 (K79) - R.I. α 2.15, β 2.20, γ 2.24 (G14)

Lead (II) borate - $5PbO\cdot 4B_2O_3$ - 1394.61 - M.P. 548 (Incong.) (G14) - R.I. α 1.91, β 1.93, γ 1.96 (G14)

Lead (II) carbonate - $PbCO_3$ (Cerussite) - 267.22 - Colorless - Rhombic - D 6.533^{20} (A26) - D.T. 293 (760 m.m.) (K14) - R.I. α 1.804, β 2.076, γ 2.078 (I8) - X-ray Lines 3.56, 2.47, 2.07, (A40)

Lead (II) carbonate, hydroxy - $Pb_3(OH)_2(CO_3)_2$ (Hydrocerussite) - 775.67 - Colorless - Hexagonal - D 6.73 (B49) - D.T. 400 (K79) - R.I. ω 2.09, ε 1.94 (I8) - X-ray Lines 3.28, 2.62, 3.61 (A40)

Lead (II) carbonate, oxy- - $PbO\cdot PbCO_3$ - 490.43 - D.T. 322 (760 m.m.) (K14)

Lead (II) cerium (IV) oxide - $PbO\cdot CeO_2$ - 395.34 - Yellow-White - 5.93 (N4)

Lead (II) chlorate - $Pb(ClO_3)_2$ - 374.12 - Colorless - Monoclinic - D 3.89 (I8)

Lead (II) chloride - $PbCl_2$ (Cotunnite) - 278.12 - Colorless - Rhombic- D 5.909^{18} (R53) - M.P. 498 (K15) - B.P. 954 (K13) - R.I. α 2.1992, β 2.2172, γ 2.2596 (I8) - X-ray Lines 3.57, 2.76, 2.50 (A41)

Lead (IV) chloride - $PbCl_4$ - 349.04 - Yellowish Liquid - D 3.18(Liq.) (I8) - M.P. -15 (I8) - B.P. 105 (I8)

Lead (II) chloride fluoride - PbClF (Nat. Matlockite) - 261.67 - Tetragonal - D 7.05 (B8) - M.P. 601 (I8) - R.I. ω 2.145, ε 2.006 (B8) - X-ray Lines 3.54, 2.25, 1.77 (A41)

Lead (II) chloride oxide - $PbO\cdot PbCl_2$ (Nat. Matlockite) - 501.33 - Colorless - Tetragonal - D 7.21 (I8) - M.P. 615 (K79) - D.T. 524 (I8) - R.I. α 2.04, β 2.15, γ 2.15 (I8)

Lead (II) chloride oxide - $PbO\cdot 2PbCl_2$ (Nat. Penfieldite) - 779.46 - Yellow - Hexagonal - R.I. ω 2.13, ε 2.21 (I8)

Lead (II) chloride oxide - $2PbO\cdot PbCl_2$ (Nat. Mendipite) - 724.54 - Rhombic - D 7.08 (I8) - M.P. 693 (K79) - R.I. α 2.24, β 2.27, γ 2.31 (I8)

Lead (II) chloride oxide - $4PbO\cdot PbCl_2$ - 1170.96 - Yellow - Tabular - M.P. 711 (R62)

Lead (II) chloride oxide - $6PbO\cdot PbCl_2$ (Nat. Lorettoite) - 1617.38 - Tetragonal - D 7.6 (I8) - R.I. ω 2.35 (Li-Line), ε 2.33 (Li-Line) (I8)

Lead (II) chromate - $PbO\cdot CrO_3$ (I) - 323.22 - Tetragonal - M.P. 844 (J3)

Lead (II) chromate - $PbO\cdot CrO_3$ (II) - 323.22 - Rhombic - Transition to I 783 (J3)

Lead (II) chromate - $PbO\cdot CrO_3$ (III) (Crocoite) - 323.22 - Monoclinic- D 6.3 (I8) - Transition to II 707 (J3) - R.I. α 2.31, β 2.37 (Li-Line), γ 2.66 (I8)

Lead (II) chromate - $3PbO\cdot 2CrO_3$ (Nat. Phoenicochroite) - 869.65 - Rhombic - D 5.75 (I8) - R.I. α 2.34, β 2.38, γ 2.65 (All for Li-lines (L18)

Lead (II) chromate - $7PbO\cdot 2CrO_3$ - 1762.49 - M.P. 854 (J3) - T.F. 744 (J3)-D.T. 830 (K79)

Lead (II) chromite - $2PbO\cdot CrO_3$ - 546.43 - M.F. 920 (J3)

Lead (II) copper phosphate - $4PbO\cdot CuO\cdot P_2O_5$ (Nat. Tsumebite) - 1114.34 Rhombic - D 6 (I8) - R.I. α 1.885, β 1.920, γ 1.956 (I8)

Lead (II) cyanate, thio- - $Pb(SCN)_2$ - 323.38 - Colorless - Monoclinic D 3.82 (I8)

Lead (II) fluoride - PbF_2 (I) - 245.21 - Colorless - Cubic - D 7.678^{24} (S30) - M.P. 824 (K15) - B.P. 1285 (K79) - R.I. >1.78 (S116) - X-ray Lines 3.44, 2.10, 1.78 (A40)

Lead (II) fluoride - PbF_2 (II) - 245.21 - Colorless - Rhombic - D 8.37^{24} (S30) - Transition to I 250 (K79)

Lead (IV) fluoride - PbF_4 - 283.21 - Colorless - Tetragonal - D 6.7 (W12) - M.P. ~ 600 (W12)

Lead (II) formate - $Pb(HCO_2)_2$ - 297.25 - Colorless - Rhombic - D 4.63 (I8)-D.T. 190 (I8) - R.I. α 1.789, β 1.852, γ 1.877 (I8) - X-ray Lines 5.2, 5.7, 3.02 (A40)

Lead (II) iodide - PbI_2 (I) - 461.05 - Tetragonal - D 5.38 (X-ray) (F49) (S119) - X-ray Lines 3.43, 2.62, 2.27 (Form not defined) (A40)

Lead (II) iodide - PbI_2 (II) - 461.05 - Tetragonal - D 5.38 (X-ray) (P49) (S119)

Lead (II) iron (II) antimony (III) sulfide - $PbS\cdot FeS\cdot 3Sb_2S_3$ (Nat. Parajamesonite I) - 1346.36 - D 5.482^{20} (Z48)

Lead (II) iron (II) antimony (III) sulfide - $4PbS\cdot FeS\cdot 3Sb_2S_3$ (Jamesonite) - 2064.19 - X-ray Lines 3.40, 2.81, 2.72 (A41)

Lead (II) iron (III) oxide - $PbO\cdot Fe_2O_3$ - 382.91 - M.P. 1530 (A34)

Lead (II) iron (III) oxide - $PbO\cdot 2Fe_2O_3$ (Plumboferrite) - 842.61 - X-ray Lines 2.93, 2.82, 2.65 (A41)

Lead (II) iron (III) oxide - $PbO\cdot 6Fe_2O_3$ - 1181.41 - Hexagonal - D 5.62 (H65)

Lead (II) iron (III) silicate - $3PbO\cdot 2Fe_2O_3\cdot 3SiO_2$ (Nat. Melanotekite) 1169.21 - Black - Rhombic - D 5.73 (I8) - R.I. α 2.12, β 2.17, γ 2.31 (I8)

Lead (II) manganese (III) silicate - $3PbO\cdot 2Mn_2O_3\cdot 3SiO_2$ (Nat. Kentrolite) - 1165.53 - Dark Reddish Brown - Rhombic - D 6.19(L18)- R.I. α 2.10, β 2.20, γ 2.310 (L18)

Lead (II) molybdate - $PbO\cdot MoO_3$ (Nat. Wulfenite) - 367.16 - Yellowish White - Tetragonal - D 6.7 (I8) - M.P. 1065 (K15) - R.I. ω 2.402, ε 2.304 (All for Li-Line) (I8) - X-ray Lines 3.17, 2.00, 1.77(A41)

Lead (II) molybdate - $2PbO\cdot MoO_3$ - 590.37 - M.P. 951 (I8)

Lead (II) nitrate - $Pb(NO_3)_2$ - 331.23 - Colorless - Cubic - D 4.535^{25} (W60) - D.T. 360 (760 m.m.) (N18) - R.I. 1.7807 (W60) - X-ray Lines 4.54, 2.36, 3.92 (A40)

Lead (II) oxalate - PbC_2O_4 - 295.23 - Colorless - D 5.28 (I8) - X-ray Lines 4.77, 4.25, 3.76 (A40)

Lead (II) oxide, sub- - Pb_2O - 430.42 - Grey - D 8.35^{18} (P14) - X-ray Lines 1.62, 1.23, 1.10; 2.85, 1.49, 2.47 (This 'compound' does not exist. Data are from a mixture of impure lead oxides.) (A41)

Lead (II) oxide - PbO (Massicotite) - 223.21 - Yellow - Rhombic - D 8.0 (I8) - M.P. 886 (K79) - Volatilize < 750 (K79) - R.I. α 2.51, β 2.61, γ 2.71 (All Li-Line) (I8) - X-ray Lines 3.06, 2.93, 2.72 (A40)

Lead (II) oxide - PbO (I) (Metastable) (Litharge) - 223.21 - Yellow - Rhombic - D 9.632^{30} (C44) - M.P. 885 (G17),(C44) - T.P. 488 (K3) - B.P. 1472 (K13)

Lead (II) oxide - PbO (II) (Stable) (Litharge) - 223.21 - Red - Tetragonal - D 9.349^{30} (C44) - Transition to I 489 (C44) (P36) - R.I. ω 2.665, ε 2.535 (All Li-Line) (I8) - X-ray Lines 3.11, 2.80, 1.863 (A40)

Lead (II, IV) oxide - Pb_2O_3 - 462.42 - Black - Triclinic - D 9.925 (C35) - T.P. 390-420 (K3) - X-ray Lines 3.18, 1.95, 1.66 (A41)

Lead (II, IV) oxide - Pb_3O_4 (Minium) - 685.63 - Vivid Red, Streak Orange Yellow - Tetragonal - D 9.1 (I8) - T.P. 530-550 (K3) - D.T. 601 (1 atm. O_2) (K79) - R.I. ω, ε mean 2.42 (Li-Line) (L18) - X-ray Lines 3.35, 2.88, 2.76 (A40)

Lead (IV) oxide - PbO_2 (Plattnerite) - 239.21 - Reddish Brown - Tetragonal - D 9.604 (S61) - D.T. 328 (1 atm. O_2) (K79) - T.P. 290-320 (K3) - D.T. 312 (760 m.m.) (K103) - R.I. ω 2.3, ε -, (I8) - X-ray Lines 3.49, 2.78, 1.84 (A40)

Lead (II) oxide - Pb_5O_8 - 1164.05 - Black - Tetragonal - D 9.514 (C35) - Transition to Pb_3O_4 390 (C34)

Lead (II) oxide, fluo - Pb_2OF_2 - 468.42 - Tetragonal - D 8.25 (X-ray) (S119) (B164)

Lead (II) oxide, hydrate - $5PbO \cdot 2H_2O$ - 1152.08 - Colorless - Monoclinic - D 7.73 (C36)

Lead (II) phosphate, meta- - $PbO \cdot P_2O_5$ - 365.17 - Colorless - M.P. 825 (K79)

Lead (II) phosphate - $PbO \cdot 4P_2O_5$ (Glass) - 791.05 - Colorless - D 3.516 (R56)

Lead (II) phosphate, pyro- - $2PbO \cdot P_2O_5$ - 588.38 - Colorless - Rhombic - D 5.8 (I8) - M.P. 824 (I8)

Lead (II) phosphate, ortho- - $3PbO \cdot P_2O_5$ - 811.59 - Colorless - Tetragonal - D 7.011 (Z33) - T.P. 782 (I8): 1015 (K79) - R.I. ω 1.970, ε 1.936 (I8) - X-ray Lines 2.90, 4.02, 2.81 (A41)

Lead (II) phosphate - $4PbO \cdot P_2O_5$ - 1034.80 - M.P. 980 (K79)

Lead (II) phosphate - $4PbO \cdot 3P_2O_5$ (Glass) - 1318.72 - Colorless - D 5.209 (R56) - R.I. < 1.83 (R56)

Lead (II) phosphate - $5PbO \cdot 2P_2O_5$ - 1399.97 - M.P. 920 (K79)

Lead (II) phosphate - $8PbO \cdot P_2O_5$ - 1927.64 - M.P. 860 (I8)

Lead (IV) phosphate - $PbO_2 \cdot P_2O_5$ - D 4.935 (X-ray) (P38) - D.T. 400-500 (P38) - X-ray Lines 2.42, 1.80, 1.54 (A41)

Lead (II) phosphate chloride - $3Pb_3(PO_4)_2 \cdot PbCl_2$ (Pyromorphite) - 2712.89 - Hexagonal - D 6.8 (I8) - M.P. 1156 (I8) - T.P. 670 (E7) - R.I. α 2.042, β 2.050, γ 2.050 (I8) - X-ray Lines 2.92, 1.52, 1.49 (A41)

Lead (II) phosphate fluoride - $3Pb_3(PO_4)_2 \cdot PbF_2$ - 2679.98 - M.P. 1098 (A17)

Lead (II) phosphate, hydrate - $10PbO \cdot 3P_2O_5 \cdot H_2O$ - 2676.00 - Colorless - X-ray Lines 2.96, 1.85, 2.06 (A41)

Lead (II) selenate - $PbSeO_4$ - 350.17 - White - Rhombic - D 6.37 (I8)

Lead (II) selenide - $PbSe$ (Clausthalite) - 286.17 - Black - Cubic - D 8.10 (I8) - M.P. 1088 (K79) - X-ray Lines 3.08, 2.18, 3.56 (A41)

Lead (II) silicate - $PbO\cdot SiO_2$ - 283.27 - Colorless - Monoclinic - D 6.264^{28} (B67) - M.P. 764 (G17) - R.I. α 1.947, β 1.961, γ 1.968 (I8)

Lead (II) silicate - $PbO\cdot SiO_2$ (Glass) - 283.27 - Colorless to Slight Yellow - D 5.835^{25} (B67) - R.I. 1.916 (M77)

Lead (II) silicate - $2PbO\cdot SiO_2$ - 506.48 - Colorless - Prism - M.P. 743 (G17) - R.I. α 2.13, β 2.15, γ 2.18 (G17)

Lead (II) silicate - $3PbO\cdot SiO_2$ - 729.69 - M.P. 710 (K86)

Lead (II) silicate - $3PbO\cdot 2SiO_2$ (Nat. Barysilite) - 789.75 - Colorless - Trigonal - D 6.72 (I8) - M.P. 690 (H67) - R.I. ω 2.07, ε 2.05 (I8)

Lead (II) silicate - $4PbO\cdot SiO_2$ (I) - 952.90 - Plate - M.P. 725 (Incong.) (G17) - R.I. α 2.31, β 2.34, γ 2.38 (G17)

Lead (II) silicate - $4PbO\cdot SiO_2$ (II) - 952.90 - Transition to I 720 (G17) - R.I. ~ 2.34 (G17)

Lead (II) silicate - $4PbO\cdot SiO_2$ (III) - 952.90 - Transition to II 140 (M21) - R.I. ~ 2.34 (G17)

Lead (II) silicate, boro- - $5PbO\cdot B_2O_3\cdot SiO_2$ - 1245.75 - Rhombic - M.P. 551 (Incong.) (G15) - R.I. ω 2.085, ε 2.04 (G15)

Lead (II) silicate, thio- - $3PbS\cdot 2SiS_2$ - 902.21 - Brick Red - D 5.470^{25} (M59) - M.P. 816 (M59)

Lead (II) sulfate - $PbSO_4$ (I) - 303.28 - Monoclinic - M.P. 1087 (K15) - X-ray Lines 3.00, 2.06, 4.26 (Form not defined) (A40)

Lead (II) sulfate - $PbSO_4$ (II) (Anglesite) - 303.28 - Colorless - Rhombic - D 6.07^{20} (L11) - Transition to I 866 (H17) - D.T. 1000 (K79) - R.I. α 1.8771, β 1.8823, γ 1.8937 (I8)

Lead (II) sulfate - $2PbO\cdot SO_3$ (Lanarkite) - 526.49 - Colorless - Monoclinic - D 6.92 (I8) - M.P. 9.77 (I8) - R.I. α 1.928, β 2.007, γ 2.036 (R23)

Lead (II) sulfate - $3PbO\cdot SO_3$ - 749.70 - Colorless - M.P. 961 (J3) - T.P. 450 (J3) - X-ray Lines 2.06, 1.86, 2.95 (A41)

Lead (II) sulfate - $4PbO\cdot SO_3$ - 972.91 - X-ray Lines 1.58, 2.50, 2.10 (A41)

Lead (II) sulfate - $5PbO\cdot SO_3$ - 1196.12 - X-ray Lines 1.98, 1.95, 2.68 (A41)

Lead (II) sulfide - PbS - 239.28 - Metallic - Cubic - D 7.590^{20} (F54) - M.P. 1114 (K15) - B.P. 1281 (K13) - R.I. 3.912 (I8) - X-ray Lines 2.97, 3.43, 2.09 (A40)

Lead (II) telluride - $PbTe$ (Altaite) - 334.82 - Cubic - D 8.16 (I8) - M.P. 920 (K79) - X-ray Lines 2.27, 3.2, 1.44 (A41)

Lead (II) tin (IV) iron (III) silicate, hydrate - $2PbO\cdot 5SnO_2\cdot Fe_2O_3\cdot SiO_2\cdot 10H_2O$ (Nat. Hochschildite) - 1599.84 - Cubic - D 4.5 (H50) - R.I. > 1.55 (H50)

Lead (II) titanate - $PbO\cdot TiO_2$ - 303.11 - Yellow - Rhombic - D 7.52 (C49) - R.I. 2.7 (R35) - X-ray Lines 2.82, 1.60, 2.30 (A40)

Lead (II) titanate - $PbO\cdot TiO_2$ - 303.11 - Tetragonal - D 8.05 (N4)

Lead (II) tungstate - $PbO\cdot WO_3$ (I) (Raspite) - 455.13 - Monoclinic - M.P. 1123 (I8) - R.I. α 2.27, β 2.27, γ 2.30 (I8)

Lead (II) tungstate - $PbO \cdot WO_3$ (II) (Stolzite) - 455.13 - Tetragonal - D 8.23 (I8) - Transition to I 877 (J3) - R.I. ω 2.2685, ε 2.182 (I8) - X-ray Lines 3.20, 2.01, 1.65 (A41)

Lead (II) tungstate - $2PbO \cdot WO_3$ - 678.34 - M.P. 900 (K79)

Lead (II) tungsten phosphate - $PbO \cdot 2WO_3 \cdot P_2O_5$ (Glass) - 829.01 - Dark Blue - D 5.756 (R56) - R.I. > 1.83 (R56)

Lead (II) tungsten phosphate - $2PbO \cdot WO_3 \cdot P_2O_5$ (Glass) - 820.30 - Yellowish - D 6.326 (R56) - R.I. 1.9685 (R56)

Lead (II) uranium (VI) phosphate, hydrate - $2PbO \cdot UO_3 \cdot P_2O_5 \cdot H_2O$ (Nat. Parsonsite) - 892.47 - R.I. α 1.85, β -, γ 1.86 (L11)

Lead (II) uranium (VI) phosphate, hydrate - $3PbO \cdot 3UO_2 \cdot P_2O_5 \cdot 5H_2O$ (Nat. Dumontite) - 1711.77 - Orthorhombic - R.I. α 1.88, β 1.89, γ - (L11)

Lead (II) uranium (VI) phosphate, hydrate - $4PbO \cdot 8UO_2 \cdot 3P_2O_5 \cdot 12H_2O$ (Dewindtite) - 3695.47 - Orthorhombic - D 4.8 (I8) - R.I. α 1.762, β 1.763, γ - (L11)

Lead (II) uranium (VI) silicate, hydrate - $PbO \cdot UO_3 \cdot SiO_2 \cdot H_2O$ (Nat. Kasolite) - 587.36 - Orthorhombic (Monoclinic ?) - D 6.46 (B43) - R.I. α 1.89, β 1.90, γ - (L11)

Lead (II) vanadate - $2PbO \cdot V_2O_5$ - 628.32 - M.P. 722 (K79)

Lead (II) vanadate - $3PbO \cdot V_2O_5$ - 851.53 - M.P. 952 (K79)

Lead (II) vanadate - $8PbO \cdot V_2O_5$ - 1967.58 - M.P. 794 (K79)

Lithium - Li - 6.940 - White - Cubic - D 0.53^{20} (A20) - M.P. 186 (A20) - B.P. 1370 (A20) - X-ray Lines 2.02, 2.50, 1.17 (A40)

Lithium aluminate - $Li_2O \cdot Al_2O_3$ - 131.82 - Rhombic ? - D 2.554^{25} (I8) - M.P. 1900-2000 (B7) - R.I. ω 1.624, ε 1.606 (H26) - X-ray Lines 1.393, 2.372, 1.518 (A40)

Lithium aluminate - $Li_2O \cdot 2Al_2O_3$ - 233.76 - A definite compound (H89)

Lithium aluminate - $Li_2O \cdot 5Al_2O_3$ - 539.58 - Cubic - D 3.606^{20} (K68) - M.P. > 1600 (Incong.) (K68) - R.I. 1.735 (K68)

Lithium aluminum fluoride - $3LiF \cdot AlF_3$ - 161.79 - M.P. 790 (F7)

Lithium aluminum phosphate, fluo-, hydrate - $2LiF \cdot Al_2O_3 \cdot P_2O_5 \cdot \frac{1}{2}H_2O$ (Amblygonite) - 304.79 - Tetragonal - R.I. α 1.578, β 1.593, γ 1.598 (L12)

Lithium aluminum silicate - $Li_2O \cdot Al_2O_3 \cdot 2SiO_2$(I)- 251.94 - Colorless - Rhombic - D 2.362 (D24) - M.P. 1397 (Incong.) (H26) - R.I. α -, β 1.531, γ 1.531 (J6) (D24)

Lithium aluminum silicate - $Li_2O \cdot Al_2O_3 \cdot 2SiO_2$ (II) (Encryptite) - 251.94 - Colorless - R.I. ω 1.572, ε 1.587 (R57)

Lithium aluminum silicate - $Li_2O \cdot Al_2O_3 \cdot 2SiO_2$ - 251.94 - Hexagonal - R.I. ω = 1.524, ε = 1.520 (W48)

Lithium aluminum silicate - $Li_2O \cdot Al_2O_3 \cdot 2SiO_2$ - Glass - 251.94 - Colorless - D 2.429 (G41) - R.I. 1.5410 (J6)

Lithium aluminum silicate - $Li_2O \cdot Al_2O_3 \cdot 4SiO_2$ (I) - 372.06 - Colorless - Monoclinic - M.P. 1417 (K79) - R.I. α -, β 1.740 (Mean), γ - (L37)

Lithium aluminum silicate - $Li_2O \cdot Al_2O_3 \cdot 4SiO_2$ (II) - 372.06 - Colorless - Trigonal - D 2.280 (D24) - Transition to I 956 - M.P. 1432 (Incong.) (H26) - R.I. ω 1.516, ε 1.522 (R55a)

Lithium aluminum silicate - $Li_2O \cdot Al_2O_3 \cdot 4SiO_2$ (Glass) - 372.06 - Colorless - D $2.388^{25.2}$ (J11) - R.I. 1.524 (J6)

Lithium aluminum silicate - $Li_2O \cdot Al_2O_3 \cdot 5SiO_2$ - 432.12 - Tetragonal - D 2.40^{12} (I8)

Lithium aluminum silicate - $Li_2O \cdot Al_2O_3 \cdot 6SiO_2$ - 492.18 - D 2.41^{11}(I8) - M.P. 1180 (B7) - R.I. (Mean) 1.502 (B7)

Lithium aluminum silicate - $Li_2O \cdot Al_2O_3 \cdot 6SiO_2$ (Glass) - 492.18 - Colorless - D 2.36 (R55a) - R.I. 1.495 (R55a)

Lithium aluminum silicate - $Li_2O \cdot Al_2O_3 \cdot 8SiO_2$ (Nat. Petalite) - 612.30 - Monoclinic - D 2.4 (I8) - M.P. 1370 (B7) (I8) - T.P. 1150 (K79) - R.I. α 1.504, β 1.510, γ 1.516 (I8)

Lithium aluminum silicate - $Li_2O \cdot Al_2O_3 \cdot 8SiO_2$ (Glass) - 612.30 - Colorless - D 2.358 (R55a) - R.I. 1.4946 (W42)

Lithium aluminum silicate - $Li_2O \cdot 3Al_2O_3 \cdot 4SiO_2$ (Nat. Cookeite) - 575.94 - Monoclinic - D 2.68 (L18) - R.I. α 1.576, β 1.579, γ 1.579 (L8)

Lithium aluminum silicate - $2Li_2O \cdot Al_2O_3 \cdot 5SiO_2$ - 462.00 - Fan-Like Crystals - D 2.388 (B7) - M.P. 965 (B7)

Lithium aluminum silicate - $3Li_2O \cdot Al_2O_3 \cdot 3SiO_2$ - 371.76 - D 2.517 (B7) - M.P. 1080 (Incong.) (B7)

Lithium aluminum silicate, boro-, hydrate - $2Li_2O \cdot 7Al_2O_3 \cdot 2B_2O_3 \cdot 6SiO_2 \cdot 12H_2O$ (Nat. Manandonite) - 1489.17 - Psendohexagonal - R.I. α -, β 1.6, γ $\alpha + .014$ (L12)

Lithium aluminum silicate, hydrate - $Li_2O \cdot 5Al_2O_3 \cdot 6SiO_2 \cdot 8H_2O$ (Cookeit) - 1044.07 - D 2.69 (B118)

Lithium antimonate, hydrate - $Li_2O \cdot Sb_2O_5 \cdot 6H_2O$ - 461.50 - X-ray Lines 3.37, 2.18, 1.81 (A41)

Lithium arsenate - $3Li_2O \cdot As_2O_5$ - 319.46 - D 3.07 (I8)

Lithium beryllium fluoride - $2LiF \cdot BeF_2$ - 98.90 - D 2.167^{30} (R10) - M.P. 457 (R57) - R.I. (Mean) $\sim$ 1.3 (G45)

Lithium beryllium fluoride, hydrate - $2LiF \cdot BeF_2 \cdot H_2O$ - 116.92 - D 1.944^{30} (R10)

Lithium borate - $Li_2O \cdot B_2O_3$ - 99.52 - Colorless - M.P. 843 (K79) - T.P. 785 (K35)

Lithium borate - $Li_2O \cdot 2B_2O_3$ - 169.16 - M.P. 930 (K79)

Lithium borate - $Li_2O \cdot 3B_2O_3$ - 238.80 - Colorless - M.P. 750 (K79)

Lithium borate - $Li_2O \cdot 4B_2O_3$ - 308.44 - Colorless - M.P. 730 (K79)

Lithium borate - $Li_2O \cdot 5B_2O_3$ - 378.08 - Colorless - M.P. $\sim$ 700 (H10)

Lithium borate fluoride - $3LiBO_2 \cdot 2LiF$ - 201.16 - M.P. 755 (K35) - T.P. 545, 585 (K35)

Lithium borate, hydrate - $Li_2O \cdot 2B_2O_3 \cdot 5H_2O$ - 259.24 - Colorless - X-ray Lines 6.9, 3.16, 2.26 (A40)

Lithium borate, hydrate - $Li_2O \cdot B_2O_3 \cdot 16H_2O$ - 387.78 - Colorless - Trigonal - D $1.38^{14.7}$ (I8) - M.P. 47 (I8)

Lithium calcium silicate - $Li_2O \cdot CaO \cdot SiO_2$ - 146.02 - Colorless - D 2.847 (S37)

Lithium calcium silicate - $4Li_2O \cdot 6CaO \cdot 5SiO_2$ - 756.30 - Colorless - D 2.566 (S37) - M.P. 1104 (S37)

Lithium calcium silicate - $6Li_2O \cdot 4CaO \cdot 5SiO_2$ - 703.90 - Colorless - D 2.591 (S37) - M.P. 1092 (S37)

Lithium carbonate - Li_2CO_3 - 73.890 - Colorless - Monoclinic - D 2.111 (I8) - M.P. 735 (K14) - D.T. 1.310 (760 m.m.) (K14) - R.I. α 1.428, β 1.567, γ 1.572 (I8) - X-ray Lines 2.80, 4.16, 2.91 (A40)

Lithium chlorate - $LiClO_3$ - 90.397 - Colorless - Rhombic ? - M.P. 127.6 (K89) - T.P. 41.5, 99 (K89) - D.T. 270 (I8)

Lithium chlorate, per- - $LiClO_4$ - 106.397 - Colorless - D 2.429 (R12) - M.P. 236 (K79) - D.T. 380 (R12)

Lithium chlorate - LiCl - 42.397 - Cubic - D 2.068^{25} (I8) - M.P. 614 (K15) - B.P. 1382 (K13) - R.I. 1.662 (S86) - X-ray Lines 3.01, 2.59, 1.83 (A41)

Lithium chloride, hydrate - $LiCl \cdot H_2O$ - 60.413 - Tetragonal - 1.78 (X-ray) (S119) - $-H_2O$ at > 98 (R12) - X-ray Lines 2.72, 1.56, 1.92 (A41)

Lithium fluoride - LiF - 25.94 - Colorless - Cubic - D 2.64030^{20} (H102) - M.P. 844 (B36), - T.P. 762, 812 (K35) - B.P. 1670 (K79)- R.I. 1.392057^{21} (L54) - X-ray Lines 2.00, 2.31, 1.422 (A40)

Lithium formate - $LiHCO_2$ - 51.958 - Colorless - Monoclinic - D 1.53 (X-ray) (B28) - M.P. 280 (S54)

Lithium gallium sulfide - $Li_2S \cdot Ga_2S_3$ - 281.58 - Brown Red - Rhombic - D 2.98 (I18) - M.P. 1020 (I18) - R.I. > 1.78 (I18)

Lithium germanate - $Li_2O \cdot GeO_2$ - 134.48 - Monoclinic - D 3.53^{21} (S36) - M.P. 1239 (S36) - R.I. α -, β 1.73, γ - (S36)

Lithium germanate - $2Li_2O \cdot GeO_2$ - 164.36 - M.P. 1298 (S36)

Lithium hydroxide - LiOH - 23.948 - Colorless - Tetragonal - D 1.46 (E19) - M.P. 462 (K15) - D.T. 924 (760 m.m.) (J27) - R.I. ω 1.464, ε 1.452 (E19) - X-ray Lines 2.75, 4.35, 2.67 (A40)

Lithium hydroxide, hydrate - $LiOH \cdot H_2O$ - 41.964 - Monoclinic - D 1.51 (P35) - X-ray Lines 2.67, 2.97, 2.44 (A40)

Lithium iron (III) fluoride - $3LiF \cdot FeF_3$ - 190.67 - Colorless - Cubic - D 2.05 (X-ray) (M55) - R.I. 1.42 (N23)

Lithium iron (III) oxide - $Li_2O \cdot Fe_2O_3$ (I) - 189.58 - Cubic - D 4.368 (P58) - R.I. 2.40 (P58) - X-ray Lines 2.07, 1.46, 2.39 (A41)

Lithium iron (III) oxide - $Li_2O \cdot 5Fe_2O_3$ - 828.38 - Cubic - D 4.77 (X-ray) (H83) (S115)

Lithium iron (II) phosphate - $Li_2O \cdot 2FeO \cdot P_2O_5$ (Nat. Triphylite) - 315.54 - Rhombic - D 3.44 (C20) - R.I. α 1.675, β 1.684, γ 1.685 (C20)

Lithium lanthanum silicate - $Li_2O \cdot La_2O_3 \cdot 2SiO_2$ - 475.84 - Colorless - Hexagonal - R.I. ω 1.870, ε 1.843 (E14)

Lithium manganate, per- - $LiMnO_4$ - 125.87 - D 2.06^{25} (C58) - Decomposition begins 190 (C58)

Lithium manganese (II, IV) aluminate, hydrate - $Li_2O \cdot MnO \cdot 5MnO_2 \cdot 2Al_2O_3 \cdot 6H_2O$ (Nat. Lithiophorite) - 627.72 - Hexagonal - D 3.37 (V11)

Lithium manganese (II) phosphate - $Li_2O \cdot 2MnO \cdot P_2O_5$ (Nat.Lithiophilite) - 313.70 - Rhombic - D 3.337 (C20) - R.I. α 1.676, β 1.679, γ 1.687 (I8)

Lithium molybdate - $Li_2O \cdot MoO_3$ - 173.83 - Colorless - Trigonal, Hexagonal - D 2.66 (X-ray) (G41) (S115) - M.P. 705 (K15)

Lithium nitrate - $LiNO_3$ - 689.48 - Colorless - Trigonal - D 2.366^{20} (H7) - M.P. 251.4 (L38) - R.I. ω 1.735, ε 1.435 (I8) - X-ray Lines 2.13, 3.58, 2.78 (A40)

Lithium nitrate, hydrate - $LiNO_3 \cdot \frac{1}{2}H_2O$ - 77.956 - $-\frac{1}{2}H_2O$ at 63 (K79)

Lithium nitrate, hydrate - $LiNO_3 \cdot 3H_2O$ - 122.996 - Prism or Needle - M.P. 29.88 (I8)

Lithium nitrite - $LiNO_2$ - 52.948 - Colorless - D 1.793 (B155) - M.P. 225 (B155) - D.T. 200 (B155)

Lithium oxalate - $Li_2C_2O_4$ - 101.900 - Rhombic - D $2.121^{17.5}$ (I8) - R.I. α 1.465, β 1.53, γ 1.696 (H38) - X-ray Lines 2.64, 4.49, 2.75 (A40)

Lithium oxide - Li_2O - 29.880 - Cubic - D $2.013^{25.2}$ (I8) - M.P. 1700 (I8) - B.P. 1200 (600 m.m.) (L40) - R.I. 1.644 (J5)

Lithium oxide, per- - Li_2O_2 - 45.880 - Tetragonal - D 2.14 (F8) - D.T. 195 (C19) - X-ray Lines 2.58, 1.59, 1.33 (A41)

Lithium phosphate, meta- - $Li_2O \cdot P_2O_5$ - 171.84 - Plate - D 2.461 (I8)

Lithium phosphate, ortho- - $3Li_2O \cdot P_2O_5$ - 231.60 - Rhombic - D $2.537^{17.5}$ (I8) - M.P. 857 (K79)

Lithium phosphate, hydrate - $Li_2O \cdot P_2O_5 \cdot 2H_2O$ - 207.87 - D 2.461 (I8) - M.P. > 100 (I8)

Lithium phosphate, hydrate - $3Li_2O \cdot P_2O_5 \cdot 24H_2O$ - 663.98 - Trigonal - D 1.645 (I8) - M.P. 100 (I8)

Lithium rhenate - $Li_2O \cdot Re_2O_7$ - 514.50 - D 4.61 (S68) - M.P. 426 (S68)

Lithium rhenate, hydrate - $Li_2O \cdot Re_2O_7 \cdot 2H_2O$ - 550.53 - D 3.69 (S68) - M.P. 87.5 (S68)

Lithium selenide - Li_2Se - 92.84 - Reddish Brown - D 2.91 (Z43)

Lithium silicate - $Li_2O \cdot SiO_2$ - 89.94 - Colorless - Rhombic - D 2.478^{25} (B67) - M.P. 1201 (K79) - R.I. ω 1.591, ε 1.611 (K74) - X-ray Lines 4.70, 2.72, 1.57 (A46)

Lithium silicate - $Li_2O \cdot SiO_2$ (Glass) - 89.94 - Colorless - R.I. 1.557 (Quenched Sample) (K76)

Lithium silicate - $Li_2O \cdot 2SiO_2$ - 150.00 - Colorless - Rhombic, Mono-Clinic - D 2.454^{25} (I8) - M.P. 1033 (Incong.) (K77) - T.P. 936 (K77) - R.I. α 1.547, β 1.550, γ 1.558 (K74) - X-ray Lines 3.67, 3.75, 1.975 (A40)

Lithium silicate - $Li_2O \cdot 2SiO_2$ (Glass) - 150.00 - Colorless - R.I. 1.535 (M77)

Lithium silicate - $2Li_2O \cdot SiO_2$ - 119.82 - Colorless - Rhombic - D 2.326^{25} (B67) - M.P. 1255 (Incong.) (K79) - R.I. α 1.602, β -, γ 1.610 (K74) - X-ray Lines 2.66, 3.97, 2.59 (A46)

Lithium silicate, fluo- - $2LiF \cdot SiF_4$ - 155.94 - D 2.88 (G41)

Lithium silicate, fluo-, hydrate - $2LiF \cdot SF_4 \cdot 2H_2O$ - 191.98 - Monoclinic - D 2.3 (I8)

Lithium sulfate - Li_2SO_4(I) - 109.946 - Colorless - Cubic - M.P. 860 (K79) - X-ray Lines 4.01, 3.16, 2.47 (Form not defined)

Lithium sulfate - Li_2SO_4 (II) - 109.946 - Colorless - Hexagonal, Rhombic

Lithium sulfate - Li_2SO_4 (III) - 109.946 - Colorless - Monoclinic - D 2.221 (I8) - T.P. 566,569 (H17); 580 (K79) - R.I. α -, β 1.465, γ - (I8)

Lithium sulfate, bi- - $LiHSO_4$ - 104.014 - Colorless - D 2.123^{18} (I8)

Lithium sulfate, hydrate - $Li_2SO_4 \cdot H_2O$ - 127.962 - Colorless - Monoclinic - D 2.06 (I8) - $-H_2O$ at 232.8 (26.7 atm.)(C7) - R.I. α 1.460, β 1.477, γ 1.488 (I8) - X-ray Lines 4.12, 5.1, 3.54 (A40)
Lithium sulfide - Li_2S - 45.946 - Colorless or Light Chocolate - Cubic - D 1.66 (I8) - M.P. 900-975 (P31)
Lithium sulfide, per- - Li_2S_2 - 78.012 - Brownish Yellow - M.P. 369.5 (P31)
Lithium telluride - Li_2Te - 141.49 - Colorless - Cubic - D 3.24 (Z43)
Lithium titanate - $Li_2O \cdot TiO_2$ - 109.78 - Colorless - Cubic - D 3.418^{20} (K68) - R.I. 2.087 (K68)
Lithium titanium fluoride - $2LiF \cdot TiF_4$ - 175.78 - M.P. 480 (G31)
Lithium tungstate - $Li_2O \cdot WO_3$ - 261.80 - Colorless - Hexagonal, trigonal - D 3.71 (X-ray) (G41) (S115) - M.P. 742 (K15)
Lithium tungstate - $Li_2O \cdot 2WO_3$ - 493.72 - Rhombic - M.P. 745 (L49) - T.P. 687 (L49)
Lithium tungstate - $Li_2O \cdot 4WO_3$ - 957.56 - Slight Yellow - M.P. 800 (H80)
Lithium zinc uranyl acetate, hydrate - $LiZn(UO_2)_3(CH_3CO_2)_9 \cdot 6H_2O$ - 1522.02 - Monoclinic - R.I. α 1.495, β -, γ 1.503 (I7a)
Lithium zirconium silicate - $4Li_2O \cdot 3ZrO_2 \cdot 5SiO_2$ - 789.48 - Slightly Yellow - D 4.024 (S37) - M.P. 1152 (S37)
*Lutecium - Lu - 174.99 - Hexagonal (A20) - D 9.74 (A20) - X-ray Lines 2.66, 1.48, 1.76 (A41)
Lutecium chloride - $LuCl_3$ - 281.36 - D 3.98 (I8) - M.P. 892 (J18)
Lutecium oxide - Lu_2O_3 - 397.98 - Cubic - D 9.42 (X-ray) (Z7)
Lutecium sulfate, hydrate - $Lu_2(SO_4)_3 \cdot 8H_2O$ - 782.31 - D 3.333^{20} (H53)

Lutetium - See Lutecium

Magnesium - Mg - 24.32 - White - Hexagonal - D 1.74^{20} (A20) - M.P. 650 (A20) - B.P. 1110 (K79) (A20) - X-ray Lines 2.45, 2.77, 2.60 (A40)
Magnesium aluminate - $MgO \cdot Al_2O_3$ (Spinel) - 142.26 - White - Cubic - D 3.578 (R27) - M.P. 2135 (K79) - R.I. 1.7258 (S11) - X-ray Lines 2.42, 1.42, 2.00 (A41)
Magnesium aluminate - $MgO \cdot Al_2O_3$ (Glass) - 142.26 - Colorless - R.I. 1.675 (G6)
Magnesium aluminate - $MgO \cdot 2Al_2O_3$ - 244.20 - White - R.I. 1.7251 (R27)
Magnesium aluminate - $MgO \cdot 3Al_2O_3$ - 346.14 - White - Cubic - D 3.62^{14} (B122) - R.I. 1.7264 (R27)
Magnesium aluminate - $MgO \cdot 4Al_2O_3$ - 448.08 - White - D 3.625 (R27) - R.I. 1.7284 (R27)
Magnesium aluminate - $MgO \cdot 5Al_2O_3$ - 550.02 - White - R.I. 1.7309 (R27)
Magnesium aluminum carbonate, hydrate - $8MgO \cdot Al_2O_3 \cdot 2CO_2 \cdot 20H_2O$ (Hydrotalcite) - 872.84 - Colorless - D.T. 180° (C3) - R.I. α 1.503, γ 1.510 (C3)
Magnesium aluminum iron (III) silicate, hydrate - $22MgO \cdot 5Al_2O_3 \cdot Fe_2O_3 \cdot 22SiO_2 \cdot 40H_2O$ (Nat. Vermiculite) - 3598.40 - X-ray Lines 14.1, 2.82, 1.52 (A41)

---

* By action of the International Union of Chemistry, Amsterdam, Holland, September 9, 1949, the official name is lutetium.

Magnesium aluminum phosphate, hydrate - $MgO \cdot Al_2O_3 \cdot P_2O_5 \cdot 9H_2O$ (Nat. Gordonite) - 446.36 - Triclinic - R.I. α 1.534, β 1.543, γ 1.558 (L12)

Magnesium aluminum silicate - $MgO \cdot Al_2O_3 \cdot SiO_2$ - 202.32 - Colorless - Rhombic - M.P. < 1400 (Incong.) (D26) - R.I. α -, β -, γ 1.649 (D26)

Magnesium aluminum silicate - $2MgO \cdot 2Al_2O_3 \cdot 5SiO_2$ (I) (Cordierite) - 584.82 - Colorless - Rhombic - M.P. 1470 (Incong.) (K79) - R.I. (Mean) 1.527 (R7) - X-ray Lines 3.00, 3.34, 8.29 (Form not defined) (A41)

Magnesium aluminum silicate - $2MgO \cdot 2Al_2O_3 \cdot 5SiO_2$ (II) (Cordierite) - 584.82 - Colorless - Monoclinic ? - T.P. 925-1150 (K79)

Magnesium aluminum silicate - $3MgO \cdot Al_2O_3 \cdot 3SiO_2$ (Nat. Pyrope) - 403.08 - Colorless - Cubic - D 3.5 (I8) - M.P. 1270 (Z34) - R.I. 1.705 (Mineral, 1.74-1.76) (I8)

Magnesium aluminum silicate - $5MgO \cdot 6Al_2O_3 \cdot 2SiO_2$ (Nat. Sapphirin) - 933.36 - Monoclinic - D 3.45 (I8) - R.I. α 1.705, β 1.709, γ 1.711 (I8)

Magnesium aluminum silicate, hydrate - $2MgO \cdot Al_2O_3 \cdot SiO_2 \cdot 2H_2O$ (Nat. Amesite) - 278.67 - X-ray Lines 6.96, 3.47, 2.46 (A41)

Magnesium aluminum silicate, hydrate - $4MgO \cdot Al_2O_3 \cdot 2SiO_2 \cdot 5H_2O$ (Nat. Colerainite) - 473.42 - Hexagonal - D 2.51 (I8) - R.I. ω 1.56, ϵ - (I8)

Magnesium aluminum silicate, hydrate - $4MgO \cdot Al_2O_3 \cdot 10SiO_2 \cdot 15H_2O$ (Nat. Pilolite) - 1134.06 - X-ray Lines 12., 2.58, 4.32 (A41)

Magnesium aluminum silicate, hydrate - $5MgO \cdot Al_2O_3 \cdot 3SiO_2 \cdot 4H_2O$ (Nat. Leuchtenbergite) - 555.78 - Monoclinic - D 2.7 (I8) - R.I. α 1.585, β 1.586, γ 1.596 (I8)

Magnesium aluminum silicate, hydrate - $5MgO \cdot Al_2O_3 \cdot 6SiO_2 \cdot 4H_2O$ (Nat. Zebedassite) - 735.96 - Rhombic - D 2.19 (I8) - R.I. α -, β 1.52, γ - (I8)

Magnesium arsenate, meta- - $MgO \cdot As_2O_5$ - 270.14 - D.T. 500 (G83)

Magnesium arsenate, pyro- - $2MgO \cdot As_2O_5$ - 310.46 - D 3.75 (C38) - D.T. 900 (G83)

Magnesium arsenate, ortho- - $3MgO \cdot As_2O_5$ - 350.78 - D.T. 1000 (G83)

Magnesium borate - $MgO \cdot B_2O_3$ - 109.96 - Colorless - D 2.6 (G41) - M.P. 988 (Incong.) (D5) - R.I. α 1.617, β -, γ 1.661 (T43)

Magnesium borate - $MgO \cdot B_2O_3$ (Glass) - 109.96 - Colorless - D 2.520 (G41)

Magnesium borate - $2MgO \cdot B_2O_3$ - 150.28 - Colorless - M.P. 1340 (D5) - R.I. α 1.588, β 1.659, γ 1.673 (T43)

Magnesium borate - $3MgO \cdot B_2O_3$ (Kotoite) - 190.60 - Colorless - Rhombic - D 2.99 (I8) - M.P. 1356 (D5) - R.I. α 1.653, β 1.654, γ 1.675 (I8)

Magnesium borate, chloro- - $5MgO \cdot MgCl_2 \cdot 7B_2O_3$ (Boracite) - 784.31 - Rhombic - D 3.01 (X-ray) (S119)

Magnesium borate, fluo- - $MgF_2 \cdot 2BF_3$ - 197.96 - Trigonal - α -, β < 1.36, γ - (I8)

Magnesium borate, hydrate - $MgO \cdot B_2O_3 \cdot 3H_2O$ (Nat. Pinnoite) - 164.01 - Colorless - Triclinic - D 2.30 (I8) - R.I. ω 1.565, ϵ 1.575 (I8)

Magnesium borate, hydrate - $MgO \cdot 2B_2O_3 \cdot 9H_2O$ - 341.74 - Colorless - Hexagonal - D 1.70 (C22) - R.I. α 1.442, β -, γ 1.485 (N28)

Magnesium borate, hydrate - $MgO \cdot 3B_2O_3 \cdot 7.5H_2O$ - 384.36 - Colorless - D 1.86 (C22) - R.I. α 1.463, β -, γ 1.508 (N28)

Magnesium borate, hydrate - $MgO \cdot 4B_2O_3 \cdot 4H_2O$ (Nat. Paternoite) - 390.94 - Colorless - R.I. α 1.509, β 1.528, γ 1.548 (B15)

Magnesium borate, hydrate - $2MgO \cdot B_2O_3 \cdot H_2O$ (Nat. Camsellite or Ascharite) (A3) - 168.30 - Colorless - Rhombic - D 2.7 (I8) - R.I. α 1.575, β 1.620, γ 1.649 (I8) - X-ray Lines 2.69, 2.08, 2.45 (A41)

Magnesium borate, hydrate - $2MgO \cdot 3B_2O_3 \cdot 13H_2O$ (Nat. Kurnakovite) - 523.77 - Colorless - Monoclinic - D 1.85 (G43) - D.T. 81-105 (G43) - R.I. α 1.489, β 1.510, γ 1.525 (G43)

Magnesium borate, hydrate - $2MgO \cdot 3B_2O_3 \cdot 15H_2O$ (Inderite) - 559.80 - Colorless - Rhombic - D 1.860 (H34) - R.I. α 1.488, β 1.502, γ 1.515 (H34) - X-ray Lines 5.00, 3.18, 7.31 (H34)

Magnesium borate, hydrate - $6MgO \cdot 3B_2O_3 \cdot 4H_2O$ (Nat. Szaibelyite) - 522.90 - D 2.63 (B85) - R.I. ω = 1.658, ε = 1.58 (B85)

Magnesium borate, hydrate - $10MgO \cdot 4B_2O_3 \cdot 3H_2O$ (Nat. Szaibelyite) - 735.81 - D 3 (I8) - R.I. ω 1.65, ε 1.59 (I8)

Magnesium calcium iron (III) aluminate - $2MgO \cdot 4CaO \cdot Fe_2O_3 \cdot Al_2O_3$ - 566.60 - X-ray Lines 2.65, 2.78, 2.05 (A41)

Magnesium carbide - MgC_2 - 48.34 - Tetragonal - D 2.07 (X-ray) (I11) - D.T. 550 (I11)

Magnesium carbonate - $MgCO_3$ (Magnesite) - 84.33 - Colorless - Trigonal - D 3.037 (I8) - D.T. 408 (760 m.m.) (K14) - R.I. ω 1.700, ε 1.509 (I8) - X-ray Lines 2.74, 2.10, 1.70 (A41)

Magnesium carbonate, hydrate - $MgCO_3 \cdot 3H_2O$ (Nat. Nesquehonite) - 138.38 - Colorless - Rhombic - D 1.850 (I8) - D.T. 320 (in CO_2) (M33) - R.I. α 1.495, β 1.501, γ 1.526 (I8)

Magnesium carbonate, hydrate - $MgCO_3 \cdot 5H_2O$ (Nat. Lansfordite) - 174.41 - Monoclinic - D 1.73 (I8) - R.I. α 1.456, β 1.468, γ 1.507 (I8)

Magnesium chlorate, per- - $Mg(ClO_4)_2$ - 223.23 - D 2.60^{28} (R12) - D.T. 251 (R12) - X-ray Lines 3.39, 4.90, 2.60 (A40)

Magnesium chloride - $MgCl_2$ - 95.23 - Colorless - Hexagonal - D 2.325 (I8) - M.P. 712 (I8) - B.P. 1418 (K13) - R.I. ω 1.675, ε 1.59 (I8) - X-ray Lines 1.80, 5.9, 2.55 (A40)

Magnesium chromate - $MgO \cdot CrO_3$ - 140.33 - Orange - D.T. 536 (760 m.m.) (R82)

Magnesium chromite - $MgO \cdot Cr_2O_3$ - 192.34 - Green - Cubic - D 4.394 (H96) - M.P. 2000 (B21) - R.I. 2.08 (D22) - X-ray Lines 2.08, 1.60, 1.47 (A41)

Magnesium cobalt (II) oxide - $MgO \cdot CoO$ - 115.26 - X-ray Lines 2.11, 1.49, 1.27 (A41)

Magnesium cobalt (III) oxide - $MgO \cdot Co_2O_3$ - 206.20 - Cubic - D 4.96 (X-ray) (H88) - X-ray Lines 2.44, 1.56, 1.44 (A41)

Magnesium cobalt (IV) oxide - $MgO \cdot CoO_2$ - 131.26 - D 5.06 (I8)

Magnesium columbate - $4MgO \cdot Cb_2O_5$ - 427.10 - Colorless or Pale Yellow - Hexagonal - D 4.4 (I8)

Magnesium fluoride - MgF_2 - 62.32 - Colorless - Tetragonal - D 3.127^{25} (K54) - M.P. 1260 (R16) - B.P. 2260 (R71) - R.I. ω 1.378, ε 1.390 (I8) - X-ray Lines 1.469, 0.998, 2.568 (A40)

Magnesium formate - $Mg(HCO_2)_2$ - 114.36 - Colorless - Monoclinic - D 1.75(?) (A36)

Magnesium gallate - $MgO \cdot Ga_2O_3$ - 227.76 - D 5.298 (X-ray) (H27) - X-ray Lines 2.50, 1.47, 1.61 (A41)

Magnesium germanate - $2MgO \cdot GeO_2$ - 185.24 - White - T.P. 1065 (J14)

Magnesium hydroxide - $Mg(OH)_2$(Brucite) - 58.34 - Colorless - Trigonal - D 2.4 (I8) - D.T. 140 (K79); 415 (L24) - R.I. ω 1.559, ε 1.580 (I8) - X-ray Lines 2.35, 4.75, 1.79 (A40)

Magnesium iron (III) oxide - $MgO \cdot Fe_2O_3$ - 200.00 - Purple Brown to Black - Cubic - D 4.481 (P55) - M.P. 1750 (R34) - R.I. 2.39 (P61) - X-ray Lines 2.51, 1.476, 2.95 (A40)

Magnesium iron (III) silicate, hydrate - $MgO \cdot Fe_2O_3 \cdot 3SiO_2 \cdot 4H_2O$ (Nat. Iddingsite) - 452.26 - Rhombic - R.I. α 1.608-1.730, β 1.650-1.840, γ 1.630-1.864 (L12)

Magnesium lanthanate - $MgO \cdot La_2O_3$ - 366.16 - Colorless - M.P. 2030 (W15)

Magnesium nitrate, hydrate - $Mg(NO_3)_2 \cdot H_2O$ (Nitromagnesite) - 166.35 - Colorless - R.I. α 1.344, β 1.506, γ 1.506 (I8)

Magnesium nitrate, hydrate - $Mg(NO_3)_2 \cdot 2H_2O$ - 184.37 - Colorless - Short prism - D 2.026^{28} (B104) - M.P. 130.9 (E26)

Magnesium nitrate, hydrate - $Mg(NO_3)_2 \cdot 6H_2O$ - 256.43 - Colorless - Monoclinic - D 1.636^{28} (B104) - M.P. 89.9 (E26) - X-ray Lines 4.42, 2.93, 3.29 (A40)

Magnesium nitrate, hydrate - $Mg(NO_3)_2 \cdot 9H_2O$ - 310.48 - Colorless - Transition to $Mg(NO_3)_2 \cdot 6H_2O$ at -14.7 (E26)

Magnesium oxide - MgO (Periclase) - 40.32 - Colorless, transparent - Cubic - D 3.5761^{28} (D40) - M.P. 2800 (K79) - B.P. 2825 (R80) - R.I. 1.73789 (S106) - X-ray Lines 2.10, 1.481, 0.9375 (C30)

Magnesium phosphate, meta--- $MgO \cdot P_2O_5$ (Nat. Finnoite) - 182.28 - Colorless - Tetragonal - R.I. ω 1.565, ε 1.575 (B80)

Magnesium phosphate, pyro- - $2MgO \cdot P_2O_5$ - 222.60 - Colorless - Monoclinic - D 3.058^{25} (A30) - M.P. 1383 (A30) - R.I. α 1.602, β 1.604, γ 1.615 (I8) - X-ray Lines 3.00, 2.09, 4.14 (Form not defined)

Magnesium phosphate, pyro- - $2MgO \cdot P_2O_5$ - amorphous - 222.60 - Colorless - D 2.598^{22} (I8) (A30)

Magnesium phosphate, ortho- - $3MgO \cdot P_2O_5$ - 262.92 - Colorless - Rhombic - M.P. 1184 (W49)

Magnesium phosphate, boro-, hydrate - $3MgO \cdot B_2O_3 \cdot P_2O_5 \cdot 8H_2O$ (Nat. Lueneburgite) - 476.69 - Colorless - Monoclinic - D 1.91 (G44) - R.I. α 1.518, β 1.540, γ 1.544 (G44)

Magnesium phosphate fluoride - $Mg_2(PO_4)F$ (Nat. Wagnerite) - 162.62 - Monoclinic - D 3.12 (I8) - M.P. 845 (Incong.) (K79) - R.I. α 1.569, β 1.570, γ 1.582 (I8)

Magnesium phosphate, hydrate - $2MgO \cdot P_2O_5 \cdot 3H_2O$ - 276.65 - Colorless - D 2.326^{15} (S22)

Magnesium phosphate, hydrate - $2MgO \cdot P_2O_5 \cdot 7H_2O$ (Nat. Newberyite) - 348.71 - Colorless - Rhombic - D 2.10 (I8) - $-4H_2O$ at 207 (S100) - R.I. α 1.514, β 1.518, γ 1.533 (I8)

Magnesium phosphate, hydrate - $2MgO \cdot P_2O_5 \cdot 15H_2O$ (Nat. Phosphorroesslerite) - 492.84 - Colorless - Monoclinic - D 1.725 (F [illegible] $-15H_2O$ at 176 (G60) - R.I. α 1.477, β 1.485, γ 1.486 (F64)

Magnesium phosphate, hydrate - $3MgO \cdot P_2O_5 \cdot 4H_2O$ - 334.98 - Monoclinic - D 1.64^{18} (R12) - X-ray Lines 4.10, 5.2, 3.23 (A40)

Magnesium phosphate, hydrate - $3MgO \cdot P_2O_5 \cdot 8H_2O$ - 407.05 - Monoclinic - D 2.41 (R12) - X-ray Lines 6.7, 2.94, 2.69 (A40)

Magnesium phosphate, hydrate - $3MgO \cdot P_2O_5 \cdot 8H_2O$ (Nat. Bobierrite) - 407.05 - Colorless - Monoclinic - D 2.41 (I8) - $-5H_2O$ at 120; $-7H_2O$ at 300; $-8H_2O$ at 400 (K40) - R.I. α 1.510, β 1.520, γ 1.543 (I8) - X-ray Lines 6.7, 2.94, 2.69 (A40)

Magnesium selenate, hydrate - $MgSeO_4 \cdot 6H_2O$ - 275.38 - Colorless - Monoclinic - D 1.928 (I8) - R.I. α 1.4856, β 1.4892, γ 1.4911 (I8)

Magnesium selenide - MgSe - 103.28 - Red Brown - Cubic - D 4.23 (H43) - R.I. > 2.42 (H1)

Magnesium silicate - $MgO \cdot SiO_2$ (Clinoenstatite) - 100.38 - Colorless - Monoclinic - D 3.193 (A11) - M.P. 1562 (Incong.) (S80) - R.I. α 1.651, β 1.654, γ 1.660 (I8) - X-ray Lines 2.86, 2.96, 1.595 (C30)

Magnesium silicate - $MgO \cdot SiO_2$ (Enstatite) - 100.38 - Colorless - Rhombic - D 3.175 (A12) - Transition to Clinoenstatite 1300, 1375 (D10) - R.I. α 1.64, β -, γ 1.65 (P72) - X-ray Lines 3.15, 2.85, 1.472 (C30)

Magnesium silicate - $MgO \cdot SiO_2$ (Protoenstatite) - 100.38 - Colorless - Transition to Enstatite 970 (T24)

Magnesium silicate - $MgO \cdot SiO_2$ (M-Amphibole) - 100.38 - Colorless - Monoclinic - D 2.872 (B67) - Transition to Clinoenstatite 1140 (K79)

Magnesium silicate - $MgO \cdot SiO_2$ (R-Amphibole) - 100.38 - Colorless - Rhombic - D 2.857 (D11) - Transition to M-Amphibole 375-475; transition to Clinoenstatite 1150 (D10)

Magnesium silicate - $MgO \cdot SiO_2$ (Glass) - 100.38 - Colorless - D 2.757 (M77) - R.I. 1.5801 (L16)

Magnesium silicate - $2MgO \cdot SiO_2$ (Forsterite) - 140.70 - Colorless - Rhombic - D 3.223 (A45a) - M.P. 1890 (1910 after temp. correction) (I8) (K79) - R.I. α 1.6359, β 1.6507, γ 1.6688 (B114) - X-ray Lines 1.733, 2.44, 2.49 (C30)

Magnesium silicate, fluo-, hydrate - $MgSiF_6 \cdot 6H_2O$ - 274.48 - Colorless - Trigonal - D 1.788 (H2) - R.I. ω 1.3439, ε 1.3602 (I8)

Magnesium silicate fluoride - $2MgO \cdot SiO_2 \cdot MgF_2$ (Nat. Norbergite) - 203.02 - Rhombic - R.I. α 1.563, β 1.567, γ 1.590 (L17)

Magnesium silicate fluoride - $6MgO \cdot 8SiO_2 \cdot MgF_2$ - 784.72 - Colorless - R.I. α 1.583, β 1.590, γ 1.598 (B113)

Magnesium silicate, hydrate - $MgO \cdot SiO_2 \cdot 2H_2O$ (Nat. Spadaite) - 136.41 - R.I. α 1.521, β 1.525, γ 1.545 (L12)

Magnesium silicate, hydrate - $2MgO \cdot 3SiO_2 \cdot 2H_2O$ (Nat. Hanusite) - 296.85 - D 2.166 (K6)

Magnesium silicate, hydrate - $2MgO \cdot 3SiO_2 \cdot 4H_2O$ (Nat. Parasepiolite) - 332.88 - Rhombic - R.I. α -, β 1.506, γ - (I8)

Magnesium silicate, hydrate - $2MgO \cdot 3SiO_2 \cdot 4H_2O$ (Nat. Sepiolite) - 332.88 - White - R.I. α 1.490, γ 1.505 (K7) - X-ray Lines 12.3, 4.29, 2.55 (K7)

Magnesium silicate, hydrate - $3MgO\cdot 2SiO_2\cdot 2H_2O$ (Antigorite) - 277.11 - Monoclinic (A35) - D 2.60 (A35) - R.I. α 1.490, β 1.502, γ 1.511 (I8)

Magnesium silicate, hydrate - $3MgO\cdot 2SiO_2\cdot 2H_2O$ (Chrysotile) - 277.11 - X-ray Lines 3.64, 7.3, 1.52 (A41)

Magnesium silicate, hydrate - $3MgO\cdot 2SiO_2\cdot 2H_2O$ (Hornblendeasbest) - 277.11 - D 2.68 (L60) - R.I. 1.595 (L60)

Magnesium silicate, hydrate - $3MgO\cdot 2SiO_2\cdot 2H_2O$ (Nat. Picrolite) - 277.11 - Colorless - X-ray Lines 7.3, 3.62, 2.52 (A41)

Magnesium silicate, hydrate - $3MgO\cdot 2SiO_2\cdot 2H_2O$ (Nat. Serpentine) - 277.11 - Rhombic(?) - D 2.5 (I8) - R.I. α -, β 1.54, γ - (I8) - X-ray Lines 7.38, 3.65, 2.51 (A41)

Magnesium silicate, hydrate - $3MgO\cdot 3SiO_2\cdot 2H_2O$ - 337.17 - Rhombic - D 2.62 (I8) - R.I. α 1.490, β 1.502, γ 1.511 (I8)

Magnesium silicate, hydrate - $4MgO\cdot 3SiO_2\cdot 6H_2O$ (Deweylite) - 449.56 - X-ray Lines 1.52, 4.59, 2.46 (A41)

Magnesium silicate, hydrate - $4MgO\cdot 5SiO_2\cdot H_2O$ (Talc) (Not $3MgO\cdot 4SiO_2\cdot H_2O$) (E25) - 479.60 - Colorless - Monoclinic - D 2.83 (E25) - R.I. α 1.539, β 1.589, γ 1.589 (I8) - X-ray Lines 3.11, 9.30, 1.52 (A41)

Magnesium sulfate - $MgSO_4$ - 120.39 - Colorless - Monoclinic - D 2.66 (I8) - M.P. 1185 (I8) - R.I. α 1.557, β -, γ 1.582 (I1) - X-ray Lines 3.55, 2.64, 2.30 (A40)

Magnesium sulfate, boro-, hydrate - $9MgO\cdot 4B_2O_3\cdot 3SO_3\ 12H_2O$ (Sulfoborite) - 935.69 - Rhombic - D 2.4 (I8) - R.I. α 1.527, β 1.540, γ 1.544 (I8)

Magnesium sulfate, hydrate - $MgSO_4\cdot H_2O$ (Nat. Kieserite) - 138.40 - Colorless - Monoclinic - D 2.57 (I8) - R.I. α 1.523, β 1.535, γ 1.586 (I8) - X-ray Lines 3.38, 4.82, 2.55 (A40)

Magnesium sulfate, hydrate - $MgSO_4\cdot 2H_2O$ - 156.42 - Colorless - D 2.3 (T28) - R.I. α -, β 1.493, γ - (R38)

Magnesium sulfate, hydrate - $MgSO_4\cdot 4H_2O$ - 192.45 - Colorless - Monoclinic - R.I. α 1.490, β 1.491, γ 1.497 (R38) - X-ray Lines 4.48, 2.95, 5.5 (A40)

Magnesium sulfate, hydrate - $MgSO_4\cdot 5H_2O$ - 210.47 - Colorless - triclinic - D 1.718 (I8) - R.I. α 1.482, β 1.492, γ 1.493 (R38)

Magnesium sulfate, hydrate - $MgSO_4\cdot 6H_2O$ - 228.48 - Colorless - Monoclinic - D 1.76 (I8) - Transition to Kieserite 68 (K79) - R.I. α 1.438, β 1.463, γ 1.465 (R38) - X-ray Lines 4.40, 2.92, 4.04 (A40)

Magnesium sulfate, hydrate - $MgSO_4\cdot 7H_2O$ (Stable Form) (Epsomite) - 246.50 - Colorless - Rhombic - D 1.68 (I8) - $-1H_2O$ at 51 (K79); $-6H_2O$ at 110, $-7H_2O$ at 350 (G29) - R.I. α 1.4326, β 1.4554, γ 1.4609 (I8) - X-ray Lines 4.22, 2.66, 5.9 (Form not defined)(A40)

Magnesium sulfate, hydrate - $MgSO_4\cdot 7H_2O$ (Unstable Form) - 246.50 - Colorless - Monoclinic - D 1.69 (R19)

Magnesium sulfide - MgS - 56.39 - Yellowish Gray - Cubic - D 2.8 (I8) - M.P. > 2000 (T32) - R.I. 2.271 (H3) - X-ray Lines 2.59, 1.83, 1.499 (A40)

Magnesium telluride - MgTe - 151.93 - Cubic - D 3.86 (Z6) - R.I. > 2.51 (~3.00) (H1)

Magnesium tin (IV) oxide - $2MgO \cdot SnO_2$ - 231.34 - Cubic - D 4.738 (N8) - M.P. > 1950 (B35) - R.I. 1.81-1.83 (B35)

Magnesium titanate - $MgO \cdot TiO_2$ (Nat. Geikielite) - 120.22 - Trigonal - D 3.98 (I8) - R.I. ω 2.31, ε 1.95 (I8) - X-ray Lines 2.70, 2.21, 1.70 (A41)

Magnesium titanate - $MgO \cdot 2TiO_2$ - 200.12 - M.P. 1680 (W17)

Magnesium titanate - $2MgO \cdot TiO_2$ - 160.54 - Cubic - D 3.52 (H29) - M.P. 1840 (W17) - X-ray Lines 2.54, 1.49, 2.11 (A41)

Magnesium tungstate - $MgO \cdot WO_3$ - 272.24 - Yellowish white - Monoclinic - D 5.66 (B129)

Magnesium uranium (VI) phosphate, hydrate - $MgO \cdot 2UO_3 \cdot P_2O_5 \cdot 3H_2O$ (Nat. Saleite) - 776.47 - Rhombic - R.I. α 1.559, β 1.570, γ 1.574 (L12)

Magnesium uranium (VI) phosphate, hydrate - $MgO \cdot 2UO_3 \cdot 3P_2O_5 \cdot 12H_2O$ (Nat. Slodowskite) - 1254.53 - R.I. α 1.613, β 1.635, γ 1.657 (L11)

Magnesium uranium (VI) silicate, hydrate - $MgO \cdot 2UO_3 \cdot 2SiO_2 \cdot 6H_2O$ (Nat. Slowdowskite) - 840.68 - Rhombic - R.I. α 1.615, β -, γ - (L12)

Magnesium zinc fluoride - $MgF_2 \cdot ZnF_2$ - 165.70 - Colorless - M.P. 1185 (M78) - R.I. ω 1.40, ε 1.41 (M78)

Magnesium zirconate - $MgO \cdot ZrO_2$ - 163.54 - Colorless - M.P. 2150 (W16)

Manganese - Mn - 54.93 - Grayish White - Cubic - D 7.43^{20} (A20) - M.P. 1254 (K79), T.P. 727, 1101, 1137 (N13) - B.P. 2150 (A20) - X-ray Lines 2.09, 1.210, 1.89 (α form); 2.10, 2.00, 1.237 (β form) (A40)

Manganese (II) aluminate - $MnO \cdot Al_2O_3$ (Manganspinel) - 172.87 - Amber - Cubic - D 4.12 (I8) - M.P. 1560 (Incong.) (H30) - R.I. ~ 1.8 (W42a) - X-ray Lines 1.398, 2.49, 2.39 (A40)

Manganese (II) aluminum phosphate, hydrate - $2MnO \cdot Al_2O_3 \cdot P_2O_5 \cdot 4H_2O$ (Nat. Eosphorite) - 457.82 - Rhombic - D 3.13 (I8) - R.I. α 1.633, β 1.655, γ 1.662 (I8)

Manganese (II) aluminum silicate - $MnO \cdot Al_2O_3 \cdot 2SiO_2$ (Manganjustite) - 292.99 - M.P. 1130 (G36)

Manganese (II) aluminum silicate - $2MnO \cdot Al_2O_3 \cdot SiO_2$ (Mangangehlenite) - 303.86 - M.P. 1175 (G36)

Manganese (II) aluminum silicate - $2MnO \cdot 2Al_2O_3 \cdot 5SiO_2$ - 646.04 - M.P. 1200 (Incong.) (S74)

Manganese (II) aluminum silicate - $3MnO \cdot Al_2O_3 \cdot 3SiO_2$ (Nat. Spessartite) - 494.91 - Cubic - D 4.180 (I8) - M.P. 1200 (S74) - R.I. 1.800 (W42a) - X-ray Lines 2.60, 1.55, 1.61 (A41)

Manganese (II) aluminum silicate, hydrate - $MnO \cdot Al_2O_3 \cdot 2SiO_2 \cdot 2H_2O$ (Nat. Karpholith) - 329.02 - Monoclinic, Rhombic - D 2.94 (I8) - R.I. α 1.615, β 1.632, γ 1.639 (L11)

Manganese (II) aluminum silicate, hydrate - $7MnO \cdot Al_2O_3 \cdot 8SiO_2 \cdot 6H_2O$ (Ganophyllite) - 1187.03 - Monoclinic - D 2.84 (I8) - R.I. α 1.705, β 1.729, γ 1.730 (I8)

Manganese (II) aluminum silicate, hydrate - $20MnO \cdot 8Al_2O_3 \cdot 21SiO_2 \cdot 12H_2O$ (Nat. Sursassite) - 3711.57 - Monoclinic ? - R.I. α 1.736, β 1.755, γ 1.766 (L12)

Manganese (II) arsenate - $3MnO \cdot As_2O_5$ (Nat. Armangite) - 442.61 Trigonal - D 4.23 (I8) - R.I. ω 2.01, ε 1.99 (L18)

Manganese (II) borate - $MnO \cdot B_2O_3$ - 140.57 - Tetragonal - M.P. 840 (K79) - R.I. α 1.617, β 1.738, γ 1.776 (L9)

Manganese (II) borate - $MnO \cdot 2B_2O_3$ - 210.21 - M.F. 950 (K79)

Manganese (II) borate - $MnO \cdot 3B_2O_3$ - 279.85 - M.P. 925 (K79)

Manganese (II) borate - $3MnO \cdot 2B_2O_3$ - 352.07 - Triclinic - D 3.61 (I8) - R.I. α 1.617, β 1.738, γ 1.776 (I8)

Manganese (II) borate, fluo- - $MnF_2 \cdot 2BF_3$ - 228.57 - Trigonal - R.I. α -, β 1.359, γ - (D19)

Manganese (II) carbonate - $MnCO_3$ (Rhodochrosite) - 114.94 - Colorless or Light Brown - Trigonal - D 3.656 (B49) - D.T. 400 (1 atm. CO_2) (K79) - R.I. ω 1.817, ε 1.597 (I8) - X-ray Lines 2.84, 1.78, 2.18 (A41)

Manganese (II) chloride - $MnCl_2$ (Scacchite) - 125.84 - Reddish - Cubic - D 2.977^{25} (I8) - M.P. 650 (I8) - B.P. 1190 (I8) - X-ray Lines 5.8, 1.84, 2.57 (A40)

Manganese (II) chromite - $MnO \cdot Cr_2O_3$ - 222.95 - Gray - Cubic - D 4.87 (I8)

Manganese (II) chromium (III) sulfide - $MnS \cdot Cr_2S_3$ - 287.22 - D 3.44^{21} (L12)

Manganese (II) columbate - $MnO \cdot Cb_2O_5$ - 336.75 - Rose Red - Rhombic - D 4.94^{18} (M29) - R.I. α -, β 2.45, γ - (L12)

Manganese (II) columbate - $3MnO \cdot 5Cb_2O_5$ - 1541.89 - Dirty Yellow - D 4.97^{17} (M29)

Manganese (II) fluoride - MnF_2 - 92.93 - Reddish - Tetragonal - D 3.891^{25} (B69) - M.P. 856 (I8) - X-ray Lines 3.45, 1.82, 2.74 (A40)

Manganese (III) fluoride - MnF_3 - 111.93 - D 3.54 (I8)

Manganese (II) formate - $Mn(HCO_2)_2$ - 144.97 - D 2.205 (I8)

Manganese (III) iron (III) oxide - $Mn_2O_3 \cdot Fe_2O_3$ (Nat. Bixbyite) - 317.56 - X-ray Lines 2.73, 1.65, 1.41 (A41)

Manganese (II) iron (III) oxide - $MnO \cdot Fe_2O_3$ (Nat. Jacobsite) - 230.63 - Black - Cubic - D 4.75 (I8) - M.P. 1570 (A34) - R.I. 2.3 (L18) - X-ray Lines 1.51, 1.11, 2.57 (A41)

Manganese (II) nitrate - $Mn(NO_3)_2$ - 178.95 - D.T. 195 (1 atm.) (K79)

Manganese (II) nitrate, hydrate - $Mn(NO_3)_2 \cdot 3H_2O$ - 232.99 - Colorless - M.P. 34.8 (I8)

Manganese (II) nitrate, hydrate - $Mn(NO_3)_2 \cdot 6H_2O$ - 287.04 - Colorless - Monoclinic - D 1.82 (I8) - M.P. 25.8 (I8)

Manganese (II) oxalate - MnC_2O_4 - 142.95 - D 2.43^{22} (I8) - D.T. 300 (In Vacuum) (B12) - X-ray Lines 5.9, 2.78, 3.58 (A40)

Manganese (II) oxide - MnO (Manganosite) - 70.93 - Green - Cubic - D 5.40^{18} (R50) - M.P. 1785 (W39) - R.I. 2.16 (I8) - X-ray Lines 2.22, 1.57, 2.56 (A41)

Manganese (II, III) oxide - $MnO \cdot Mn_2O_3$ (Hausmannite) - 228.79 - Brownish Red - Tetragonal - D 4.816^{25} (K99) - M.P. 1590 (W15) - R.I. ω 2.46, ε 2.15 (I8) - X-ray Lines 2.48, 2.75, 1.54 (A41)

Manganese (III) oxide - Mn_2O_3 (I) (Nat. Braunite) - 157.86 - Brownish Black - D 4.50 (I8) - -1/3 O at 940 (In Air) (M47) - X-ray Lines 2.72, 1.66, 1.42 (Form not defined) (A41)

Manganese (III) oxide - Mn_2O_3 (II) - 157.86 - D 4.802^{25} (K99) - Transition to I 600 (D36) - X-ray Lines 2.68, 1.656, 1.414 (Form not defined) (A40)

Manganese (IV) oxide - MnO_2 - 86.93 - D 4.943 (K99) - D.T. 530 (In Air),565 (1 atm. O_2) (K79) - -½O at 530 (M47) - X-ray Lines 3.11, 2.40, 1.62 (A40)

Manganese (IV) oxide - MnO_2 (Nat. Pyrolusite) - 86.93 - Black - Rhombic - D 5.03 (I8) - X-ray Lines 3.12, 1.62, 2.40 (A41)

Manganese (II) oxide, hydrate - $MnO \cdot H_2O$ (Nat. Pyrochroite) - 88.95 - Colorless - Trigonal - D 3.258^{13} (I8) - R.I. ω 1.723, ε 1.681 (I8) -X-ray Lines 2.44, 1.81, 1.23 (A41)

Manganese (III) oxide, hydrate - $Mn_2O_3 \cdot H_2O$ (Nat. Groutite) - 175.88 - Brown-Black - Rhombic - D 4.144 (G81)

Manganese (III) oxide, hydrate - $Mn_2O_3 \cdot H_2O$ (Nat. Manganite) - 175.88 - Black - Rhombic - D 4.3 (L18) - R.I. α 2.24, β 2.24, γ 2.53 (All Li-Line) (L18) - X-ray Lines 3.40, 2.65, 2.41 (A41)

Manganese (II) phosphate - $2MnO \cdot P_2O_5$ - 283.82 - Colorless - Monoclinic - D 3.707^{25} (I8) - M.P. 1196 (A30) - R.I. α 1.695, β 1.704, γ 1.710 (A30)

Manganese (II) phosphate, hydrate - $3MnO \cdot P_2O_5 \cdot 3H_2O$ (Nat. Reddingite) - 408.80 - Rhombic - D 3.1 (I8) - R.I. α 1.651, β 1.656, γ 1.683 (I8)

Manganese (II) phosphate, hydrate - $3MnO \cdot P_2O_5 \cdot 7H_2O$ - 480.86 - Reddish -White - X-ray Lines 2.61, 2.38, 3.45 (A40)

Manganese (II) phosphate, hydrate - $5MnO \cdot 2P_2O_5 \cdot 4H_2O$ (Nat. Palaite) - 710.63 - Flesh-Colored - Monoclinic - D 3.17 (I8) - R.I. α 1.652, β 1.656, γ 1.660 (I8)

Manganese (II) phosphate, hydrate - $5MnO \cdot 2P_2O_5 \cdot 5H_2O$ (Nat.Hureaulite) - 728.65 - Monoclinic - D 3.18 (I8) - R.I. α 1.647, β 1.654, γ 1.660 (I8)

Manganese (II) selenate, hydrate - $MnO \cdot SeO_3 \cdot 2H_2O$ - 233.92 - Rhombic - D 2.949 (I8)

Manganese (II) selenate, hydrate - $MnO \cdot SeO_3 \cdot 5H_2O$ - 287.97 - Pale Red - Trigonal - D 2.334 (I8)

Manganese (II) selenide - MnSe - 133.89 - Grey - Cubic - D 5.59^{15} (I8)

Manganese (IV) selenide - $MnSe_2$ - 212.85 - Cubic - D 5.32 (X-ray) (E16) (S115)

Manganese (II) silicate - $MnO \cdot SiO_2$ (Rhodonite) - 130.99 - Pink - Triclinic - D 3.707^{25} (B67) - M.P. 1297 (Incong.) (K79) - R.I. α 1.733, β -, γ 1.739 (W42)

Manganese (II) silicate - $MnO \cdot SiO_2$ - Glass - 130.99 - D 3.48 (W42) - R.I. 1.700 (W42)

Manganese (II) silicate - $2MnO \cdot SiO_2$ (Tephroite) - 201.92 - Flesh Red - Rhombic - D 4.05 (T39) - M.P. 1340 (Incong.) (W39) - R.I. α 1.7720, β 1.8038, γ 1.8143 (G65) - X-ray Lines 1.81, 2.88, 2.56 (A41)

Manganese (II, III) silicate - $MnO \cdot 3Mn_2O_3 \cdot SiO_2$ - 604.57 - Tetragonal D 4.78 (I8) - X-ray Lines 2.72, 1.66, 1.42 (A41)

Manganese (II) silicate, arseno-, hydrate - $12MnO \cdot As_2O_5 \cdot 9SiO_2 \cdot 7H_2O$ (Nat. Schallerite) - 1747.63 - Trigonal (?) - D 3.368 (I8) - R.I. ω 1.704, ε 1.679 (I8)

Manganese (II) silicate, fluo-, hydrate - $MnF_2 \cdot SiF_4 \cdot 6H_2O$ - 305.09 - Pink - Hexagonal - D 1.904^{18} (I8) - R.I. ω 1.357, ε 1.374 (W42)

Manganese (II) silicate, hydrate - $5MnO \cdot 2SiO_2 \cdot H_2O$ (Nat. Alleghanite) - 492.79 - X-ray Lines 1.80, 2.86, 2.64 (A41)

Manganese (II) silicate, hydrate - $8MnO \cdot 7SiO_2 \cdot 5H_2O$ (Nat. Bementite) - 1077.94 - Rhombic - D 2.90 (I8) - R.I. α 1.602, β 1.632, γ 1.632 (I8) - X-ray Lines 3.6, 2.85, 2.52 (A41)

Manganese (II) sulfate - $MnSO_4$ - 151.00 - Colorless to Reddish - D 3.181^{25} (M58) - M.P. 700 (I8) - D.T. 1110 (0.296 atm.) (R12)

Manganese (III) sulfate - $Mn_2(SO_4)_3$ - 398.06 - Brown, Green - Hexagonal - D 3.24^{15} (B24) - D.T. 320 (D27)

Manganese (II) sulfate, hydrate - $MnSO_4 \cdot H_2O$ (Szmikite) - 169.01 - Pale Pink - Monoclinic - D 2.874^{25} (M58) - $-H_2O$ at 117 (K79) - R.I. α 1.562, β 1.595, γ 1.632 (I8)

Manganese (II) sulfate, hydrate - $MnSO_4 \cdot 2H_2O$ - 187.03 - D 2.526 (I8) - $-H_2O$ at 57 (K79)

Manganese (II) sulfate, hydrate - $MnSO_4 \cdot 3H_2O$ - 205.04 - D 2.356 (I8) - $-H_2O$ at 40 (K79)

Manganese (II) sulfate, hydrate - $MnSO_4 \cdot 4H_2O$ - 223.06 - Pale Red - Monoclinic - D 2.201^{25} (M58) - $-H_2O$ at 18 (K79) - R.I. α 1.508, β 1.518, γ 1.522 (W42) - X-ray Lines 3.51, 3.15, 2.59 (A40)

Manganese (II) sulfate, hydrate - $MnSO_4 \cdot 5H_2O$ - 241.08 - Pale Pink - Triclinic - D 2.046^{25} (M58) - M.P. 54 (M29) - R.I. α 1.495, β 1.508, γ 1.514 (W42)

Manganese (II) sulfide - MnS (Alabandite) - 87.00 - Red, Green - Cubic - D 3.93^{22} (A23) - M.P. 1530 (G36) - R.I. 2.70 (Li-Line) (I8) - X-ray Lines 2.61, 1.85, 1.170 (A40)

Manganese (IV) sulfide - MnS_2 (Hauerite) - 119.06 - Reddish Brown - Cubic - D 3.465 (B74) - R.I. 2.69 (Li-Line) (I8) - X-ray Lines 3.04, 2.72, 2.49 (A41)

Manganese (II) tantalate - $MnO \cdot Ta_2O_5$ - 512.69 - Black - Rhombic - D 7.03 (I8) - R.I. α 2.22, β 2.25, γ 2.29 (I8)

Manganese (IV) telluride - $MnTe_2$ - 310.15 - Dark Green - Cubic - D 6.11 (X-ray) (E16) (S115)

Manganese (II) titanate - $MnO \cdot TiO_2$ (Pyrophanite) - 150.83 - Yellow - Trigonal - D 4.54 (I8) - M.P. 1360 (Incong.) (G69) - R.I. ω 2.481, ε 2.210 (I8) - X-ray Lines 2.78, 2.57, 1.74 (A41)

Manganese (II) titanate - $2MnO \cdot TiO_2$ - 221.76 - Cubic - D 4.49 (H87) - M.P. 1455 (G69) - X-ray Lines 2.61, 1.54, 2.17 (A41)

Manganese (II) tungstate - $MnO \cdot WO_3$ (Nat. Huebnerite) - 302.85 - Brownish Red - Monoclinic - D 7.2 (I8) - R.I. α 2.17, β 2.22, γ 2.32 (I8) - X-ray Lines 2.96, 4.83, 3.77 (A41)

Mercury - Hg - 200.61 - Silvery Liquid - Rhombohedral - D 13.55^{20} (A20) - M.P. -38.87 (A19) (A20) (U2) - B.P. 356.57 (A19) - X-ray Lines 2.255, 2.771, 1.750 (A40)

Mercury (II) antimony (III) sulfide - $HgS \cdot 2Sb_2S_3$ (Livingstonite) - 912.12 - X-ray Lines 2.99, 3.75, 3.45 (A41)

Mercury (I) chloride - Hg_2Cl_2 (Calomel) - 472.13 - Colorless or Yellowish - Tetragonal - D 7.15^{25} (I8) - M.P. 525 (K43) - B.P. 383 (K79) - R.I. ω 1.9733, ε 2.6559 (I8) - X-ray Lines 3.155, 4.143, 1.962 (A40)

Mercury (II) chloride - $HgCl_2$ - 271.52 - Colorless - Rhombic - D 5.44^{25} (I8) - M.P. 277 (I8) - B.P. 305 (K79) - R.I. α 1.725, β 1.8590, γ 1.965 (I8) - X-ray Lines 4.34, 4.08, 3.36 (A41)

Mercury (I) fluoride - Hg_2F_2 - 439.22 - Pale Yellow - Cubic - D 8.699^{25} (B69) - M.P. 570 (I8)

Mercury (II) fluoride - HgF_2 - 238.61 - Colorless - Cubic - D 9.073^{25} (B69) - M.P. 645 (I8) - B.P. 650 (I8)

Mercury (I) oxide - Hg_2O - 417.22 - Brownish Black - D 9.8 (I8) - D.T. 100 (I8)

Mercury (II) oxide - HgO - 216.61 - Red and Yellow - Rhombic - D Red 11.19, Yellow 11.24 (L42) - D.T. 496 (1 atm. O_2) (K79) - D.T. 100 (I8) - R.I. α 2.37, β 2.50, γ 2.65 (All for Li-Line) (I8) - X-ray Lines 2.96, 2.83, 2.40 (A40)

Mercury (I) selenide - Hg_2Se - 480.18 - Violet - Cubic - D 8.877 (M29)

Mercury (II) selenide - HgSe (Tiemannite) - 279.57 - Gray - Plates - D 8.266 (X-ray) (Z4) - X-ray Lines 3.48, 2.13, 1.82 (A41)

Mercury (I) selenite - $Hg_2O \cdot SeO_2$ - 528.18 - D.T. 180 (I8)

Mercury (I) selenite - $3Hg_2O \cdot 4SeO_2$ - 1695.50 - D 7.350^{14} (M29)

Mercury (I) sulfate - Hg_2SO_4 - 497.29 - Colorless - Monoclinic - D 7.56 (I8) - X-ray Lines 3.03, 4.42, 4.19 (A40)

Mercury (II) sulfate - $HgSO_4$ - 296.68 - Colorless - Rhombic - D 6.47 (I8) - M.P. 850 (K15) - X-ray Lines 3.90, 3.40, 3.01 (A40)

Mercury (II) sulfide - HgS (I) (Metacinnabarite) - 232.68 - Black - Hexagonal - D 7.69 (R29) - M.P. 1450 (120 atm.) (T33) - S.P. 580 (I8) - R.I. ω 2.58, ε 2.82 (6710 A) (A9) - X-ray Lines 3.38, 2.07, 1.76 (A41)

Mercury (II) sulfide - HgS (II) (Cinnabar) - 232.68 - Red - Hexagonal - D 8.15 (R29) - Transition to I 386 (K17) (R29) - R.I. ω 2.85, ε 3.20 (6710 A) (M41) - X-ray Lines 2.85, 3.36, 1.97 (A40)

Mercury (II) telluride - HgTe (Coloradoite) - 328.22 - M.P. $\sim$ 580 (K79) - X-ray Lines 2.28, 1.96, 1.32 (A41)

Molybdenum - Mo - 95.95 - Silvery White - Cubic - D 10.2^{20} (A20) - M.P. 2625 (A19) (A20) (U2) - B.P. 4800 (A20) - X-ray Lines 2.23, 1.283, 0.994 (A40)

Molybdenum (III) chloride - $MoCl_3$ - 202.32 - Brownish Red - Needle - D 3.578^{25} (B56)

Molybdenum (V) chloride - $MoCl_5$ - 273.24 - Dark Green - Iodine-Like Crystals - D 2.928^{25} (B56) - M.P. 97 (K79) - B.P. 268 (I8)

Molybdenum (VI) fluoride - MoF_6 - 209.95 - Colorless - D 2.551^{18} (R70) M.P. 17 (I8) - B.P. 35 (K79)

Molybdenum (VI) fluoride oxide - MoF_4O - 187.95 - Colorless - D 3.001 (I8) - M.P. 98 (I8) - B.P. 180 (I8)

Molybdenum (VI) fluoride oxide - MoF_2O_2 - 165.95 - Colorless - Radiated Crystal - D 3.494 (I8) - S.P. 270 (I8)

Molybdenum (III) oxide - Mo_2O_3 - 239.90 - Black, Opaque - X-ray Lines 3.42, 2.42, 1.71 (A40)

Molybdenum (IV) oxide - MoO_2 - 127.95 - Brown - Monoclinic (not tetragonal) (H6) - D 6.4 (B47) (G41) - X-ray-Lines 3.42, 2.42. 1.71 (A41)

Molybdenum oxide - Mo_4O_{11} - 559.80 - Reddish Violet (H6)

Molybdenum oxide - β-$Mo_{18}O_{52}$ - 2559.10 - Needle - D 4.26 (H6)

Molybdenum (VI) oxide - MoO_3 - 143.95 - Colorless with Bluish Shade - Rhombic - D 4.692^{21} (H91) - M.P. 795 (R25) - T.P. 700 (R25) - B.P. 1151 (K13) - X-ray Lines 3.25, 3.80, 3.46 (A40)

Molybdenum (VI) oxide, hydrate - $MoO_3 \cdot H_2O$ - 161.97 - Colorless - Hexagonal - $-H_2O$ at 120 (K79) - X-ray Lines 6.6, 3.47, 3.06 (A40)

Molybdenum (VI) oxide, hydrate - $MoO_3 \cdot 2H_2O$ - 179.98 - Colorless - Monoclinic - D 3.124^{15} (I8) - $-H_2O$ at 61 (K79);$-2H_2O$ 200 (G41)

Molybdenum (III) phosphate - $Mo_2O_3 \cdot 3P_2O_5$ - 665.78 - Yellow - D 3.28° (I8)

Molybdenum (III) sulfide - Mo_2S_3 - 288.10 - Steel gray - Needle - D 5.9 (I8)

Molybdenum (IV) sulfide - MoS_2 (Molybdenite) - 160.08 - Bluish Lead-Gray - Hexagonal - D 4.80^{14} (I8) - M.P. 1185 (I8) - S.P. 450 (J34) R.I. 4.8 (6000 A) (T58) - X-ray Lines 6.16, 2.26, 1.03 (A40)

Molybdenum (III) telluride - Mo_2Te_3 - 574.73 - Dark Gray - D 7.35^{15} (M72) - D.T. 960 (M72)

Molybdenum (IV) telluride - $MoTe_2$ - 351.17 - Gray - Hexagonal - D 7.60^{15} (M72)

Neodymium - Nd - 144.27 - Hexagonal - D 7.05^{20} (A20) - M.P. 840 (A19) (A20) (U2) - X-ray Lines 2.78, 2.94, 1.55 (A41)

Neodymium chloride - $NdCl_3$ - 250.64 - Wine Red - Prism, Hexagonal - D 4.17 (K37) - M.P. 761 (K37) - B.P. $>$ 1000 (V13)

Neodymium fluoride - NdF_3 - 201.27 - Pale Lilac-Colored - Hexagonal - D 6.52 (X-ray) (O6) - M.P. 1410 (W13)

Neodymium germanate - $Nd_2O_3 \cdot GeO_2$ - 441.14 - Rhombic (G33)

Neodymium hydroxide - $Nd(OH)_3$ - 195.29 - Hexagonal - D 4.93 (X-ray) (F57)

Neodymium molybdate - $Nd_2O_3 \cdot 3MoO_3$ - 768.39 - Violet - Tetragonal - D 5.14 (I8) - M.P. 1176 (I8) - R.I. ω 2.0239, ε 2.0218 (5700 A) (Z25)

Neodymium nitrate, hydrate - $Nd(NO_3)_3 \cdot 6H_2O$ - 438.39 - Violet - Plates - M.P. 67.5 (Incong.) (F67) - T.P. 22 (F67)

Neodymium oxide - Nd_2O_3 - 336.54 - Bluish Violet - Trigonal, Rhombic - D 7.24 (I8)

Neodymium phosphate - $Nd_2O_3 \cdot P_2O_5$ (I) - 478.50 - Monoclinic (M67) - D 5.500 (X-ray) (M67)

Neodymium phosphate - $Nd_2O_3 \cdot P_2O_5$ (II) - 478.50 - Hexagonal (M67) - D 4.328 (X-ray) (M67)

Neodymium selenide - Nd_2Se_3 - 525.42 - Violet Black - D 6.67 (K48) -

Neodymium silicate - $Nd_2O_3 \cdot SiO_2$ - 396.60 - Violet (S95) - Hexagonal (G34)

Neodymium silicate - $Nd_2O_3 \cdot 2SiO_2$ - 456.66 - Monoclinic (G34) - Melts Incong. (G34)

Neodymium sulfate, hydrate - $Nd_2(SO_4)_3 \cdot 8H_2O$ - 720.87 - Rose Red - Monoclinic - D 2.856^{20} (H53) - R.I. α 1.5413, β 1.5505, γ 1.5621 (I8)

Neodymium sulfide - Nd_2S_3 - 384.74 - Greenish Yellow - D 5.34^{25} (K49) - M.P. 2200 (In Vacuum) (P46)

Neptunium - $_{93}Np$ - Synthetic element with mass numbers 231, 236, 237, 238 and 239 for the known isotopes (S45)
Neptunium - $_{93}Np^{237}$ - Silvery - D 17.8 (F59)
Neptunium (IV) oxide - $Np^{237}O_2$ - Apple Green (K6a) - Cubic - D 11.14 (X-ray) (M4) - Stable at 1100 (K6a)
Neptunium oxide - Np_3O_8 - Chocolate Brown - -O at 600 (K6a)
Neptunium silicide - $NpSi_2$ - Triclinic - D 9.03 (X-ray) (Z22a)

Nickel - Ni - 58.69 - White - Cubic - D 8.90^{20} (A20) - M.P. 1455 (A19) (A20) (U2) (V1) - T.P. 360 (K79) - B.P. 2730 (A20) - X-ray Lines 2.038, 1.067, 1.766 (A40)
Nickel (II) aluminate - $NiO \cdot Al_2O_3$ - 176.63 - Blue - Cubic - D 4.45 (D22) - M.P. 2030 (W18) - R.I. 1.875 (D22) - X-ray Lines 1.421, 2.43, 2.01 (A40)
Nickel (II) arsenate - $3NiO \cdot As_2O_5$ (Nat. Xanthiosite) - 453.89 - Yellow - D 4.98 (I8)
Nickel (II) arsenite - $NiO \cdot As_2O_3$ - 272.51 - Tetragonal - D 4.76 (X-ray) (S119) (S92)
Nickel bismuth sulfide - $Ni_3Bi_2S_2$ (Parkerite) - 658.20 - Bronze Color - D 8.44 (M51) - X-ray Lines 2.85, 2.23, 1.645 (M51)
Nickel (II) borate, fluo-, - $NiF_2 \cdot 2BF_3$ - 232.33 - Pseudorhombic - R.I. $\alpha > 1.47$, β 1.48, $\gamma < 1.50$ (D19)
Nickel (II) carbonate - $NiCO_3$ - 118.70 - D.T. 325 (Max. Rate) (S89)
Nickel (II) chloride - $NiCl_2$ - 129.60 - Yellow - Pseudocubic - D 3.52 (B52) - M.P. 1001 (F22) - S.P. 987 (K13) - X-ray Lines 2.46, 5.7, 2.96 (A40)
Nickel (II) chromate - $NiO \cdot CrO_3$ - 174.70 - Rhombic - D 4.20 (X-ray) (S119) (B119)
Nickel (II) chromite - $NiO \cdot Cr_2O_3$ - 226.71 - Dark Green - Cubic - D 5.16 (D22) - R.I. 2.29 (Li-Line) (D22) - X-ray Lines 2.50, 1.60, 1.47 (A41)
Nickel (II) fluoride - NiF_2 - 96.69 - Yellowish Green - Tetragonal - D 4.60^{25} (B69) - X-ray Lines 3.30, 2.55, 1.719 (A40)
Nickel fluoride, hydrate - $NiF_2 \cdot 4H_2O$ - 168.75 - X-ray Lines 4.85, 4.10, 2.98 (A40)
Nickel (II) iron (III) oxide - $NiO \cdot Fe_2O_3$ - 234.39 - Reddish Violet - Cubic - D 5.34 (D22) - M.P. 1660 (A34) - R.I. 2.69 (D22)
Nickel (II) nitrate - $Ni(NO_3)_2$ - 182.71 - D.T. 302 (1 atm.) (K79)
Nickel (II) nitrate, hydrate - $Ni(NO_3)_2 \cdot 6H_2O$ - 290.80 - Emerald Green - Monoclinic - D 2.05 (I8) - $-2H_2O$ at 54.0 (S57) - X-ray Lines 5.5, 3.78, 2.74 (A40)
Nickel (II) oxalate - NiC_2O_4 - 146.71 - D 2.235 (I8)
Nickel (II) oxide - NiO (Bunsenite) - 74.69 - Green - Cubic - D 6.8 (W42) - M.P. 1955 (W19) - R.I. 2.37 (Li-Line) (W42) - X-ray Lines 2.09, 1.48, 2.41 (A41)
Nickel (II, III) oxide - Ni_3O_4 - Gray-Black - Cubic - D.T. (to NiO and O_2) < 1000 (K79)
Nickel (III) oxide - Ni_2O_3 - 165.38 - Black - D 4.83 (I8)
Nickel (II) oxide, hydrate - $NiO \cdot H_2O$ - 92.71 - Green - D 4.09 (X-ray) (N7) - X-ray Lines 2.32, 1.75, 1.55 (A41)

Nickel (II, III) oxide, hydrate - $Ni_3O_4 \cdot 2H_2O$ - 276.10 - D 3.412^{32} (I8)

Nickel (II) phosphate, hydrate - $3NiO \cdot P_2O_5 \cdot 8H_2O$ - 510.16 - Apple-Green - Plates - X-ray Lines 6.6, 2.91, 4.80 (A40)

Nickel (II) selenate, hydrate - $NiO \cdot SeO_3 \cdot 6H_2O$ - 309.75 - Tetragonal - D 2.31 (I8) - R.I. ω 1.5393, ε 1.5125 (I8)

Nickel selenide - Ni_3Se_2 - 333.54 - X-ray Lines 1.73, 3.02, 2.12 (A41)

Nickel (II) selenide - NiSe - 137.65 - Gray or Silver White - Hexagonal - D 8.46 (I8) - X-ray Lines 2.72, 2.04, 1.82 (A41)

Nickel (IV) selenide - $NiSe_2$ - 216.61 - Cubic - D 6.69 (X-ray) (J38)

Nickel (II) silicate - $2NiO \cdot SiO_2$ - 209.44 - Light Green - Rhombic - D 4.92 (X-ray) (T14)

Nickel (II) silicate, fluo-, hydrate - $NiF_2 \cdot SiF_4 \cdot 6H_2O$ - 308.85 - Apple Green - Trigonal - D 2.13 (I8) - R.I. ω 1.3910, ε 1.4066 (I8) - X-ray Lines 4.67, 4.16, 2.58 (A40)

Nickel (II) silicate, hydrate - $3NiO \cdot 2SiO_2 \cdot 2H_2O$ (Nat. Bastite) - 380.22 - Monoclinic - R.I. α -, β 1.682, γ - (A32)

Nickel (IV) silicate, hydrate - $2NiO_2 \cdot 3SiO_2 \cdot 2H_2O$ (Nat. Connarite) - 365.59 - Yellowish Green - Hexagonal - D 2.5 (L18) - R.I. ω 1.59, ε 1.56 (L18)

Nickel (II) sulfate - $NiSO_4$ - 154.76 - Yellowish Green - Cubic - D 3.543^{25} (M58) - D.T. 848 (760 m.m.) (W51) - X-ray Lines 2.55, 4.30, 3.58 (A40)

Nickel (II) sulfate,-hydrate - $NiSO_4 \cdot H_2O$ - 172.77 - Green - D 2.885^{25} (M58) - $-H_2O$ at 250 (D12) - X-ray Lines 3.33, 4.77, 3.02 (A40)

Nickel (II) sulfate, hydrate - $NiSO_4 \cdot 6H_2O$ (I) - 262.85 - Green - Monoclinic - Transition to $NiSO_4 \cdot H_2O$ 200 (D12) - X-ray Lines 4.26 4.6, 2.72 (Form not defined)

Nickel (II) sulfate, hydrate - $NiSO_4$ $6H_2O$ (II) - 262.85 - Blue - Tetragonal - D 2.07 (I8) - Transition to I 53.3 (B33) - R.I. 1.511, ε 1.487 (I8)

Nickel (II) sulfate, hydrate - $NiSO_4 \cdot 7H_2O$ (Morenosite) - 280.87 - Green - Rhombic, Monoclinic - D 1.976 (M58) - Transition to $NiSO_4 \cdot 6H_2O$ (II) 31.5 (B33) - R.I. α 1.4693, β 1.4893, γ 1.4923 (W42) - X-ray Lines 4.20, 5.3, 2.85 (A40)

Nickel (I) sulfide - Ni_2S - 149.45 - Yellow - D 5.66 (M29) - M.P. 645 (K15)

Nickel (I, II) sulfide - Ni_3S_2 - 240.20 - Pale Yellow - D 5.82 (P27) - M.P. 790 (F63) - T.P. 545 (F63) - X-ray Lines 2.87, 1.82, 1.66 (A41)

Nickel sulfide - Ni_6S_5 - 512.47 - Yellow - Rhombic needle (L62)

Nickel (II) sulfide - NiS (Millerite) - 90.76 - Yellow - Trigonal - D 5.25 (W41) - M.P. 990 (K79) - T.P. 400 (B71) - X-ray Lines 2.96, 2.83, 1.87 (A41)

Nickel (II, III) sulfide - Ni_3S_4 (Polydymite or Violarite) - 304.33 - Gray-Black - Cubic - D 4.7 (I8) - X-ray Lines 2.86, 1.68, 2.37 (A41)

ickel (IV) sulfide - NiS_2 - 122.82 - Cubic - D 4.39 (B71) - X-ray Lines 1.73, 1.10, 2.88 (A41)

ickel telluride - $NiTe_2$ (Nat. Melonite) - 313.91 - Hexagonal - D 7.72 (P27)

Nickel (II) titanate - $NiO \cdot TiO_2$ - 154.59 - Canary Yellow - Rhombohedral - D 5.08 (T14)
Nickel (II) tungstate - $NiO \cdot WO_3$ - 306.61 - Brown - Rhombic - D 6.88 (I8)

Niobium - See Columbium

Nitrogen - $N(N_2)$ - 14.008 - Colorless Gas - Hexagonal (A20) - D 1.1649×10^{-3} - M.P. -210.0 (A19) (A20) (U2) - T.P. -237.55 (K79) - B.P. -195.8 (A20) (K79)
Nitrogen (III) fluoride - NF_3 - 71.01 - Colorless Gas - M.P. -208.5 (R79) - T.P. -219 (R79) - B.P. -129.0 (M37)
Nitrogen (V) oxide - N_2O_5 - 108.016 - Colorless - Rhombic - D 2.05 (G41) - M.P. 30 (I8) - S.P. 32.5 (D3)
Nitrogen (V) sulfide - N_2S_5 - 188.346 - Deep Red - Iodine-Like Crystals - D 1.901^{18} (M29) - M.P. 10-11 (M29)

Osmium - Os - 190.2 - Bluish White - Hexagonal - D 22.5^{20} (A20) - M.P. 2700 (A19) (A20) (U2) - B.P. 5500 (A20) - X-ray Lines 2.07, 2.36, 2.16 (A40)
Osmium (VI) fluoride - OsF_6 - 304.2 - Green - M.P. 50-120 (G41) - B.P. 203 (I8)
Osmium (VIII) fluoride - OsF_8 - 342.2 - Yellow - Needle - D $2.74^{\text{B.P.}}$ (H46) - M.P. 34.5 (I8) - B.P. 47.5 (K13)
Osmium (IV) oxide - OsO_2 - 222.2 - Brown - Cubic, Hexagonal - D 11.38^{21} (K93)
Osmium (VIII) oxide - OsO_4 - 254.2 - Yellow - Monoclinic - D 4.91 (I8) - M.P. 56 (K15) - B.P. 130 (K13) - R.I. 1.56 (45°) (I8)
Osmium (VIII) oxide - OsO_4 - 254.2 - Colorless - Monoclinic - D 4.95^{21} (K93) - M.P. 42 (K15) - B.P. 130 (K13)
Osmium (IV) sulfide - OsS_2 - 254.3 - Dark Bluish Gray - Cubic - D 9.475 (M26)

Oxygen - $O(O_2)$ - 16.0000 - Colorless Gas - D 1.3318×10^{-3} (A20) - M.P. -218.8 (A19) (A20) (U2) - T.P. -229.7, -249.4 (K79) - B.P. -182.97 (I8a) - X-ray Lines 2.75, 2.56, 1.60 (-252°) (A40)

Palladium - Pd - 106.7 - Steel White - Cubic - D 12.0^{20} (A20) - M.P. 1555 (K79) - B.P. 4000 (A20) - X-ray Lines 1.16, 2.21, 1.92 (A41)
Palladium (II) chloride - $PdCl_2$ - 177.6 - Rose Red - Rhombic, Cubic - D 4.00^{18} (B25) - M.P. 500 (I8) - X-ray Lines 5.3, 2.39, 1.64 (A40)
Palladium (II) fluoride - PdF_2 - 144.7 - Brown - Tetragonal - D 5.82 (X-ray) (R69) - X-ray Lines 1.84, 3.47, 2.76 (A41)
Palladium (III) fluoride - PdF_3 - 163.7 - Black - Rhombic - D 5.06 (R69) - X-ray Lines 1.73, 3.73, 2.76 (A41)
Palladium (II) nitrate - $Pd(NO_3)_2$ - 230.72 - Brown-Yellow - Rhombic - X-ray Lines 4.22, 2.80, 5.8 (A40)
Palladium (II) oxide - PdO - 122.7 - Black Green - Tetragonal - D 8.70^{20} (L43) - D.T. 877 (I8) - X-ray Lines 1.30, 2.60, 1.65 (A41)

Palladium (II) selenide - PdSe - 185.7 - M.P. < 960 (I8)

Palladium (II) sulfide - PdS - 138.8 - Black - Tetragonal - D 6.69 (X-ray) (G5) - M.P. 970 (W27) - X-ray Lines 2.83, 2.57, 1.72 (A41)

Palladium (IV) sulfide - PdS_2 - 170.8 - Dark Brown - D 4.833^{25} (B64)

Phosphorus - P (Yellow) - 30.98 - Yellow - Cubic - D 1.82^{20} (A20) - M.P. 44.1 (A19) (A20) (U2) - T.P. -68 (K79) - B.P. 280 (A20) - R.I. 2.117 (W42)

Phosphorus - P (Violet) - 30.98 - Violet - D 2.10^{20} (I10) - M.P.592.5 (K79) - S.P. 417 (K13)

Phosphorus - P (Black) - 30.98 - Black - Graphite-Like - D 2.70 (I10) - Transition to Red P 550 (H97) - S.P. 453 (K13) - X-ray Lines 2.56, 3.36, 1.64 (A41)

Phosphorus - P (Red) - 30.98 - Hexagonal - R.I. ω 2.72, ε 3.17 (R55) - X-ray Lines 5.66, 5.39, 3.30; 5.71, 2.63, 4.48 (R55)

Phosphorus - P (Red) - 30.98 - Red - Monoclinic - D 2.20 (L9) - M.P. 590 (43 atm.) (A19) (U2) - B.P. 725 (H97) - X-ray Lines 4.23, 3.67, 3.28 (A41)

Phosphorus - P (Red) - 30.98 - Tetragonal - R.I. ω 2.72, ε 3.15 (R55) - X-ray Lines 2.65, 5.84, 5.58 (R55)

Phosphorus - P (Red) - 30.98 - Triclinic - R.I. α 3.11, β 3.20, γ 3.21 (R55) - X-ray Lines 6.21, 5.68, 5.32 (R55)

Phosphorus - P (Red) (Amorphous) - 30.98 - R.I. 2.9 (R55)

Phosphorus, Acids - See Phosphorus oxide, hydrate

Phosphorus (III) chloride - PCl_3 - 137.35 - Colorless Liquid - D 1.574^{21} (Liquid) (I8) ; 2.015^{-183} (Solid) (B70) - M.P. -92 (B59) B.P. 76 (762 m.m.) (B70) - R.I. 1.516^{14} (I8)

Phosphorus (V) chloride - PCl_5 - 208.26 - Colorless - Tetragonal - D 2.114^{26} (B70) - M.P. 163 (Closed Tube) (S114) - B.P. 162 (I8) - X-ray Lines 4.98, 2.78, 4.69 (A40)

Phosphorus (V) chloride oxide - $POCl_3$ - 153.35 - Colorless Liquid - D 1.675 (Liquid) (I8); 2.066^{-78} (Solid) (B70) - M.P. 1.25 (I8) - B.P. 108 (B70) - R.I. 1.460^{25} (I8)

Phosphorus (III) fluoride - PF_3 - 87.98 - Colorless Gas - M.P. -151.5 (T7) - B.P. -101.8 (T7)

Phosphorus (V) fluoride - PF_5 - 125.98 - Colorless Gas - M.P. -83 (I8) - B.P. -75 (I8)

Phosphorus (V) fluoride oxide - PF_3O - 103.98 - Colorless Gas - M.P. -39.1 (785 m.m.) (T7) - B.P. -39.7 (T7)

Phosphorus (III) oxide - P_4O_6 - 219.92 - Colorless - Monoclinic - D 2.135^{21} (I8) - M.P. 23.8 (K15) - B.P. 173 (K13) - R.I. 1.5403 (M29)

Phosphorus (III, V) oxide - $P_4O_6 \cdot P_4O_{10}$ - 503.84 - Colorless - Rhombic - D 2.537^{23} (I8) - M.P. > 100 (I8) - S.P. ∼ 180 (I8)

Phosphorus (V) oxide - P_4O_{10} (I) - 283.92 - Colorless - Rhombic - D 2.284^{20} (G39) - M.P. (Tabular) > 570, (Accular) 569 (K79) - B.P. 591 (K13) - R.I. α 1.545, β 1.578, γ 1.589 (H63) - X-ray Lines 4.26, 2.865, 2.62 (H63)

Phosphorus (V) oxide - P_4O_{10} (II) - 283.92 - Colorless - Monoclinic, Triclinic - D 2.420^{27} (C8) - S.P. 358.9 (S82) - R.I. 1.470-1.485 (C8)

Phosphorus (V) oxide - P_4O_{10} - 283.92 - Hexagonal - R.I. ω 1.469, ε 1.471 (H63) - X-ray Lines 5.44, 5.19, 3.035 (H63)
Phosphorus (V) oxide - P_4O_{10} (Amorphous)- 283.92 - Colorless - D 2.291^{27} (C8)
Phosphorus (V) oxide - P_2O_5 - Glass - 141.96 - Colorless - D 2.737^{27} (C8) - R.I. 1.517 (H63)
Phosphorus oxide - P_2O_7 - 173.96 - Dark Violet - D.T. 130 (S12)
Phosphorus (III) oxide, hydrate - $P_2O_3 \cdot 3H_2O$ - 164.01 - Colorless - D 1.651^{21} (I8) - M.P. 73.6 (I8)
Phosphorus (V) oxide, hydrate - $P_2O_5 \cdot H_2O$ (Glass) - 159.98 - Colorless - D 2.176^{-78} (B58)
Phosphorus (V) oxide, hydrate - $P_2O_5 \cdot 2H_2O$ - 177.99 - Colorless - Needle - M.P. ~ 61 (K79) - R.I. 1.3435 (M29)
Phosphorus (V) oxide, hydrate - $P_2O_5 \cdot 3H_2O$ - 196.01 - Colorless - Rhombic - D 1.884^{18} (I8) - M.P. 42.35 (L9) - B.P. 122 (M29)
Phosphorus (V) oxide, hydrate - $P_2O_5 \cdot 4H_2O$ - 214.02 - Colorless - M.P. 29.32 (R46)
Phosphorus (V) oxide, hydrate - $2P_2O_5 \cdot 3H_2O$ - 337.97 - Colorless - D 1.889^{18} (R3) - M.P. 34 (R3)
Phosphorus (III) sulfide - P_4S_6 - 316.32 - Yellowish White - M.P. 290 (I) - B.P. 490 (I8)
Phosphorus (V) sulfide - P_4S_{10} - 444.58 - Yellow - Cubic - D 2.062 (G50) - M.P. 276 (I8) - B.P. 514 (I8) - R.I. > 1.8 (G50) - X-ray Lines 2.90, 6.7, 4.90 (A40)
Phosphorus (V) sulfide oxide - $P_2S_3O_2$ - 190.16 - Yellowish White - M.P. 300 (I8)
Phosphorus (V) sulfide oxide - $P_4S_4O_6$ - 348.18 - Colorless - Tetragonal - M.P. 102 (I8) - B.P. 295 (I8)

Platinum - Pt - 195.23 - Tin White - Cubic - D 21.45^{20} (A20) - M.P. 1773.5 (A19) (A20) (U2) (K79) - X-ray Lines 2.25, 1.95, 1.382 (A40)
Platinum (II) chloride - $PtCl_2$ - 266.14 - Olive Green - D 6.054^{25} (K39) - D.T. 576 (K104) - R.I. 1.98 (L10)
Platinum (IV) chloride - $PtCl_4$ - 337.06 - Grayish Brown - D 4.303^{25} (K39)
Platinum (IV) oxide - PtO_2 - 227.23 - Black - D 10.2 (L2)
Platinum (IV) phosphate - $PtO_2 \cdot P_2O_5$ - 369.19 - Pale Greenish Yellow - D 4.856 (I8) - D.T. > 600 (I8)
Platinum (IV) selenide - $PtSe_2$ - 353.15 - Gray - D 7.65 (I8)
Platinum (VI) selenide - $PtSe_3$ - 432.11 - Black - D 7.15 (I8)
Platinum (II) sulfide - PtS - 227.30 - Gray - D 10.1^{26} (B60) - X-ray Lines 3.01, 1.91, 1.50 (A41)
Platinum (IV) sulfide - PtS_2 - 259.36 - Gray - Trigonal - D 7.66 (B60)

Plutonium - $_{94}Pu$ - Synthetic element with mass numbers 234, 236, 238, 239, and 241 for the known isotopes (S45)
Plutonium - $_{94}Pu^{239}$ - 239.08 (S101) - D 21 (S101 (S119)
Plutonium (III) bromide - $PuBr_3$ - 478.83 - B.P. 681 (J35)
Plutonium (III) chloride - $PuCl_3$ - 345.45 - B.P. 760 (J35)
Plutonium (II) oxide - PuO - 255.08 - Cubic - D 13.89 (X-ray) (M70)

Plutonium (III) oxide - Pu_2O_3 - 526.16 - Cubic (M70)

Plutonium (IV) oxide - PuO_2 - 271.08 - Cubic - D 11.44 (X-ray) (M70)

Plutonium silicide - $PuSi_2$ - 295.20 - Tetragonal - D 9.12 (X-ray) (Z22a)

Plutonium (III) sulfide - Pu_2S_3 - 574.36 - Cubic - D 8.41 (X-ray) (Z21)

Plutonium (III) sulfide, oxy- - Pu_2O_2S - 542.23 - Hexagonal - D 9.95 (X-ray) (Z22)

Polonium - Po - ~210 - Rhombohedral, Cubic (B22) - D 9.24 (X-ray) (R44) - M.P. 600 (A19) (U2)

Potassium - K - 39.096 - Silvery - Cubic - D 0.86^{20} (A20) - M.P. 63 (A20) - B.P. 770 (A20) - X-ray Lines 3.75, 2.16, 2.65 (A40)

Potassium aluminate - $K_2O \cdot Al_2O_3$ - 196.13 - Colorless - Cubic - M.P. > 1650 (B138) - R.I. 1.603 (B138) - X-ray Lines 2.72, 1.57, 1.21 (A41)

Potassium aluminate - $K_2O \cdot 12Al_2O_3$ (Miscalled 'Beta Alumina') (R24) - 1317.47 - Colorless - Hexagonal - D 3.370 (R24) - D.T. 1650 (R24) - R.I. ω 1.670, ϵ 1.639 (R24) - X-ray Lines 1.397, 2.505, 2.69 (A40)

Potassium aluminum borate - $K_2O \cdot 2Al_2O_3 \cdot 3B_2O_3$ (Nat. Rhodizite) - 506.99 - Colorless - Cubic - D 3.4 (I8) - R.I. 1.69 (I8)

Potassium aluminum fluoride - $KF \cdot AlF_3$ - 142.07 - Colorless - X-ray Lines 3.07, 1.78, 2.32 (A41)

Potassium aluminum fluoride - $2KF \cdot AlF_3$ - 200.16 - Rhombic, Monoclinic - R.I. > 1.34, < 1.445 (T46)

Potassium aluminum fluoride - $3KF \cdot AlF_3$ - 258.26 - Colorless - M.P. 1025 (F7) (I8) - T.P. 300 (F7) (I8)

Potassium aluminum fluoride, hydrate - $2KF \cdot AlF_3 \cdot H_2O$ - 218.18 - Colorless - D 2.58 (B134) - D.T. 270 (R12)

Potassium aluminum phosphate - $K_2O \cdot Al_2O_3 \cdot 2P_2O_5$ - 480.05 - Colorless - Monoclinic - D 2.8 (O15)

Potassium aluminum phosphate - $3K_2O \cdot 2Al_2O_3 \cdot 3P_2O_5$ - 912.34 - Colorless - Monoclinic - D 2.3^{20} (O15)

Potassium aluminum silicate - $K_2O \cdot Al_2O_3 \cdot SiO_2$ - 256.19 - Colorless - Cubic - R.I. 1.540 (B106)

Potassium aluminum silicate - $K_2O \cdot Al_2O_3 \cdot 2SiO_2$ (I) (Kaliophilite) - 316.25 - Colorless - Rhombic - M.P. 1800 (B106) - R.I. α 1.528, β 1.535, γ 1.536 (B106) - X-ray Lines 3.67, 3.02, 2.10 (Form not defined) (A41)

Potassium aluminum silicate - $K_2O \cdot Al_2O_3 \cdot 2SiO_2$ (II) (Kaliophilite) - 316.25 - Colorless - Hexagonal - D 2.6 (I8) - Transition to I 1550 (I8) - R.I. ω 1.532, ϵ 1.527 (B106)

Potassium aluminum silicate - $K_2O \cdot Al_2O_3 \cdot 2SiO_2$ (Kalsilite) - 316.25 - Colorless - X-ray Lines 3.94, 3.09, 2.58 (A41)

Potassium aluminum silicate - $K_2O \cdot Al_2O_3 \cdot 2SiO_2$ (Glass) - 316.25 - Colorless - R.I. 1.508 (B106)

Potassium aluminum silicate - $K_2O \cdot Al_2O_3 \cdot 4SiO_2$ (I) (Leucite) - 436.37 - Colorless - Cubic - D 2.47 (I8) - M.P. 1686 (B111) - R.I. 1.508 (B111) - X-ray Lines 3.24, 3.42, 5.3 (Form not defined) (A41)

Potassium aluminum silicate - $K_2O \cdot Al_2O_3 \cdot 4SiO_2$ (II) (Leucite) - 436.37 - Colorless - Tetragonal - D 2.507 (M92) - Transition to I 620 (M29) - R.I. α 1.508, β 1.508, γ 1.509 (B106)

Potassium aluminum silicate - $K_2O \cdot Al_2O_3 \cdot 4SiO_2$ (Glass) - 436.37 - Colorless - D 2.44 (S95) - R.I. 1.490 (B106)

Potassium aluminum silicate - $K_2O \cdot Al_2O_3 \cdot 6SiO_2$ (Orthoclase) - 556.49 - Colorless - Monoclinic - D 2.56 (I8) - M.P. 1170 (Incong.) (I8) - R.I. α 1.518, β 1.524, γ 1.526 (I8) - X-ray Lines 3.18, 4.02, 3.80 (A41)

Potassium aluminum silicate - $K_2O \cdot Al_2O_3 \cdot 6SiO_2$ (Microcline) - 556.49 - Colorless - Triclinic - D 2.56 (I8) - M.P. 1150 (I8) - R.I. α 1.522, β 1.526, γ 1.530 (I8) - X-ray Lines 3.22, 1.80, 2.16 (A41)

Potassium aluminum silicate - $K_2O \cdot Al_2O_3 \cdot 6SiO_2$ (Nat. Adular) - 556.49 - D 2.575 (D31) - M.P. 1145 (M93) - X-ray Lines 3.31, 3.23, 1.79 (A41)

Potassium aluminum silicate - $K_2O \cdot Al_2O_3 \cdot 6SiO_2$ (Glass) - 556.49 - Colorless - D 2.370 (D31)

Potassium aluminum silicate, hydrate - $K_2O \cdot Al_2O_3 \cdot 3SiO_2 \cdot 2H_2O$ (Nat. Natrolite) - 412.34 - X-ray Lines 7., 2.95, 3.08 (A41)

Potassium aluminum silicate, hydrate - $K_2O \cdot 3Al_2O_3 \cdot 6SiO_2 \cdot 2H_2O$ (Nat. Muscovite) - 796.40 - Colorless - Monoclinic - D 2.9 (I8) - R.I. α 1.561, β 1.590, γ 1.594 (I8) - X-ray Lines 2.56, 9.9, 4.47 (A40)

Potassium aluminum sulfate - $K_2SO_4 \cdot Al_2(SO_4)_3$ - 516.40 - Colorless - Hexagonal - D 2.75^{20} (S13) - D.T. 718 (K91) - R.I. ω 1.545, ε 1.533 (W42)

Potassium aluminum sulfate, hydrate - $K_2SO_4 \cdot Al_2(SO_4)_3 \cdot 24H_2O$ (Alum) - 948.78 - Colorless - Cubic - D 1.74 (K91) - R.I. 1.4562 (W33) - X-ray Lines 4.29, 4.03, 3.24 (A40)

Potassium aluminum sulfate, hydrate - $K_2SO_4 \cdot Al_2(SO_4)_3 \cdot 24H_2O$ (Kalmite) 948.78 - Colorless - Hexagonal - D 1.75 (I8) - R.I. ω 1.456, ε 1.429 (W42)

Potassium aluminum sulfate, hydrate - $K_2SO_4 \cdot Al_2(SO_4)_3 \cdot 24H_2O$ - 948.78 - Colorless - Monoclinic - R.I. α 1.430, β 1.452, γ 1.458 (I8)

Potassium aluminum sulfate, hydroxide - $K_2SO_4 \cdot Al_2(SO_4)_3 \cdot 4Al(OH)_3$ (Alunite) - 828.37 - Colorless - Trigonal - D 2.60 (I8) - R.I. ω 1.572, ε 1.592 (I8) - X-ray Lines 2.98, 1.893, 4.94 (A40)

Potassium antimonate, fluo- - $KF \cdot SbF_5$ - 274.86 - Rhombic - D 3.384^{17} (L13) - D.T. 285 (L13) - R.I. α -, β 1.362, γ - (L13)

Potassium arsenate - $K_2O \cdot As_2O_5$ - 324.01 - M.P. 650 (K79)

Potassium arsenate - $2K_2O \cdot As_2O_5$ - 418.20 - M.P. 996 (K79)

Potassium arsenate - $3K_2O \cdot As_2O_5$ - 512.40 - Colorless - Needle - M.P. 1310 (K79)

Potassium arsenate - $5K_2O \cdot 3As_2O_5$ - 1160.42 - M.P. 630 (Incong.) (K79)

Potassium arsenate, hydrate - $K_2O \cdot As_2O_5 \cdot 2H_2O$ - 360.04 - Colorless - Tetragonal - D 2.867 (I8) - M.P. 288 (I8) - R.I. ω 1.567, ε 1.518 (I8)

Potassium barium carbonate - $K_2CO_3 \cdot BaCO_3$ - 335.57 - Colorless - M.P. 800 (I8)

Potassium barium phosphate - $K_2O \cdot 2BaO \cdot P_2O_5$ (I) - 542.87 - Colorless - Tetragonal - D 4.34 (K41) (S115)

Potassium barium phosphate - $K_2O \cdot 2BaO \cdot P_2O_5$ (II) - 542.87 - Colorless - Rhombic - D 3.97 (X-ray) (K41) (S115)

Potassium beryllium fluoride - $2KF \cdot BeF_2$ - 163.21 - Colorless - Rhombic - D 2.24 (X-ray) (S119) (O3) - M.P. Red Heat (G41)

Potassium beryllium silicate - $K_2O \cdot 3BeO \cdot 4SiO_2$ - 409.49 - Cubic - D 2.531 (G7) - R.I. 1.523 (G7)

Potassium beryllium silicate - $2K_2O \cdot 3BeO \cdot 6SiO_2$ (Glass) - 623.80 - Colorless - D 2.478 (L6) - R.I. 1.5201 (L6)

Potassium beryllium sulfate - $K_2SO_4 \cdot BeSO_4$ - 279.35 - M.P. 900 (K79) - D.T. 1000 (liquid, 0.265 atm.) (K79)

Potassium bismuth (III) sulfide - $K_2S \cdot Bi_2S_3$ - 624.46 - Cubic - D 4.75 (X-ray) (S119) (B97)

Potassium borate - $K_2O \cdot B_2O_3$ - 163.83 - Colorless - Hexagonal - D 2.348 (Z8) - M.P. 968 (C51) - R.I. ω 1.526, ε 1.450 (C51)

Potassium borate - $K_2O \cdot 2B_2O_3$ - 233.47 - Colorless - M.P. 815 (R41)

Potassium borate - $K_2O \cdot 3B_2O_3$ - 303.11 - M.P. 825 (Incong.) (K79)

Potassium borate - $K_2O \cdot 4B_2O_3$ - 372.75 - Colorless - M.P. 857 (R41)

Potassium borate - $K_2O \cdot 5B_2O_3$ (I) - 442.39 - Colorless - M.P. 780 (Incong.) (R42)

Potassium borate - $K_2O \cdot 5B_2O_3$ (II) - 442.39 - Colorless - M.P. 760 (Incong.) (R42) - Transition to I 720 (R42)

Potassium borate - $K_2O \cdot 5B_2O_3$ (III) (Metastable Low Temp. Form) - 442.39 - Colorless - Transition to I 690 (R42)

Potassium borate, fluo- - $KF \cdot BF_3$ (I) - 125.92 - Colorless - Cubic - M.P. 530 (B83) - X-ray Lines 3.07, 2.08, 3.40 (Form not defined) (A40)

Potassium borate, fluo- - $KF \cdot BF_3$ (II) - 125.92 - Colorless - Rhombic - D 2.50 (I8) - Transition to I 278 (V16) - R.I. α 1.324, β 1.325, γ 1.325 (Z28)

Potassium borate, hydrate - $K_2O \cdot 2B_2O_3 \cdot 5H_2O$ - 323.55 - Colorless - Monoclinic, Hexagonal - D 1.74 (R12) - X-ray Lines 5.60, 3.52, 3.37 (A40)

Potassium borate, hydrate - $K_2O \cdot 5B_2O_3 \cdot 8H_2O$ - 586.52 - D 1.740 (Z8)

Potassium borate phosphate - see Potassium phosphate borate

Potassium bromide - KBr - 119.012 - Colorless - Cubic - D 2.75 (I8) - M.P. 748 (K79) - B.P. 1380 (K79) - R.I. 1.5599 (20°) (F44) - X-ray Lines 3.28, 2.33, 1.467 (A40)

otassium cadmium phosphate - $K_2O \cdot 2CdO \cdot P_2O_5$ - 492.97 - Colorless - Rhombic - D 3.8 (I8)

otassium calcium aluminum phosphate, hydrate - $K_2O \cdot 4CaO \cdot 4Al_2O_3 \cdot 4P_2O_5 \cdot 14H_2O$ (Nat. Englishite) - 1546.26 - Rhombic ? - R.I. α 1.570, β -, γ 1.572 (L12)

otassium calcium aluminum silicate, hydrate - $K_2O \cdot 2CaO \cdot 3Al_2O_3 \cdot 10SiO_2 \cdot 12H_2O$ (Nat. Christianite) - 1328.96 - D 2.204 (W62)

otassium calcium aluminum silicate, hydrate - $K_2O \cdot 4CaO \cdot 2Al_2O_3 \cdot 24SiO_2 \cdot H_2O$ (Nat. Milarite) - 1981.85 - Hexagonal - D 2.57 (I8) - R.I. ω 1.532, ε 1.529 (I8)

otassium calcium carbonate - $K_2CO_3 \cdot CaCO_3$ - 238.292 - Colorless - Rhombic - D 2.465 (E13) - M.P. 813 (760 m.m.) (E13) - R.I. ω 1.530, ε 1.48 (E13)

Potassium calcium carbonate - $K_2CO_3 \cdot 2CaCO_3$ - 338.382 - Colorless - M.P. $\sim$ 835 (45 atm. CO_2) (R12)

Potassium calcium phosphate - $K_2O \cdot CaO \cdot P_2O_5$ - 292.23 - Hexagonal - D 2.7 (I8)

Potassium calcium phosphate - $K_2O \cdot 2CaO \cdot P_2O_5$ (Rhenanite) - 348.31 - Colorless - Hexagonal - D 2.32 (X-ray) (K41) (S115) - T.F. 705 (F50)

Potassium calcium silicate - $K_2O \cdot CaO \cdot SiO_2$ - 210.33 - Colorless - Hexagonal - M.P. 1630 (M84) - R.I. ω 1.600, ε 1.605 (M84)

Potassium calcium silicate - $K_2O \cdot 2CaO \cdot 9SiO_2$ - 746.89 - Colorless - Monoclinic, Triclinic - M.P. 1050 (Incong.) (M84) - R.I. α 1,515, β -, γ 1.535 (M84)

Potassium calcium silicate - $K_2O \cdot 3CaO \cdot 6SiO_2$ (I) - 622.79 - Colorless - Rhombic - M.P. 1020 (Incong.) (K79) - R.I. α 1.575, β -, γ 1.59 (M84)

Potassium calcium silicate - $K_2O \cdot 3CaO \cdot 6SiO_2$ (II) - 622.79 -Colorless - Rhombic - M.P. 1020 (M84) - T.P. 985 (K79) - R.I. α 1.56, β -, γ 1.57 (M84)

Potassium calcium silicate - $K_2O \cdot 23CaO \cdot 12SiO_2$ - 2104.75 - Colorless - D 3.24 (X-ray) (B124) - R.I. α 1.695, β -, γ 1.703 (I17)

Potassium calcium silicate - $2K_2O \cdot CaO \cdot 3SiO_2$ - 424.64 - Colorless - Pseudo-cubic - M.P. 1005 (M84) - R.I. 1.572 (M84)

Potassium calcium silicate - $2K_2O \cdot CaO \cdot 6SiO_2$ - 604.82 - Colorless - Monoclinic, Triclinic - M.P. 959 (M84) - R.I. α 1.540, β 1.541, γ 1.544 (M84)

Potassium calcium silicate - $4K_2O \cdot CaO \cdot 10SiO_2$ - 1033.45 - Colorless - Hexagonal - M.P. 946 (M84) - R.I. α 1.537, β -, γ 1.548 (M84)

Potassium calcium silicate, hydrate - $K_2O \cdot 8CaO \cdot 16SiO_2 \cdot 16H_2O$ (Nat. Apophyllite) - 1792.05 - Tetragonal - D 2.35 (I8) - R.I. ω 1.537, ε 1.535 (I8)

Potassium calcium sulfate - $K_2SO_4 \cdot 2CaSO_4$ - 446.55 - Colorless - Cubic - D 2.63 (X-ray) (R5) (S115) - M.P. 1020 (K79) - T.F. 936 (K79)

Potassium carbonate - K_2CO_3 - 138.202 - Colorless - 4 Modifications - D 2.428^{18} (H91) - M.P. 895 (K79) - T.P. 250, 428, 622 (M7) - D.T. 1400 (0.047 atm. CO_2) (K79) - R.I. α 1.426, β 1.531, γ 1.541 (W42) - X-ray Lines 2.80, 2.61, 2.97 (A40)

Potassium carbonate, bi- - $KHCO_3$ - 100.114 - Colorless - Monoclinic - D 2.1 (G41) - D.T. 173 (760 m.m.) (K14) - R.I. α 1.380, β 1.482, γ 1.578 (I8) - X-ray Lines 2.84, 3.68, 2.62 (A40)

Potassium carbonate fluoride - $K_2CO_3 \cdot KF$ - 196.30 - Colorless - M.P. 683 (V14)

Potassium carbonate, hydrate - $K_2O \cdot 2CO_2 \cdot H_2O$ (Nat. Kalicinite) - 200.228 - Colorless - Monoclinic - D 2.17 (I8) - D.T. < 200 (I8) - R.I. α -, β 1.482, γ - (I8)

Potassium carbonate, hydrate - $2K_2CO_3 \cdot 3H_2O$ - 330.452 - Colorless - Monoclinic - D 2.043 (I8) - X-ray Lines 2.76, 3.01, 6.9 (A40)

Potassium chlorate - $KClO_3$ - 122.553 - Colorless - Monoclinic - D 2.338^{21} (H91) - M.P. 368 (K79) - R.I. α 1.410, β 1.517, γ 1.524 (Z5) - X-ray Lines 3.45, 2.79, 2.86 (A40)

Potassium chlorate, per- - $KClO_4$ (I) - 138.553 - Colorless - Cubic - D 2.18 (X-ray)(H49) - M.P. 525 (G41) - D.T. 400 (K79) - X-ray Lines 3.48, 3.13, 2.88 (Form not defined) (A40)

Potassium chlorate, per- - $KClO_4$ (II) - 138.553 - Colorless - Rhombic - D 2.5298 (W58) - Transition to I 299.5 (W17) - R.I. α 1.4717, β 1.4724, γ 1.4759 (W58)

Potassium chloride - KCl - 74.553 - Colorless - Cubic - D 1.98827^{20} (H102) - M.P. 770 (K15) - B.P. 1411 (K79) - R.I. 1.49042^{18} (W58) - X-ray Lines 3.12, 2.21, 1.812 (A40)

Potassium chromate - $K_2O\cdot CrO_3$ (I) - 194.20 - Red - Hexagonal - M.P. 984 (K15) - X-ray Lines 2.96, 4.28, 3.07 (Form not defined) (A40)

Potassium chromate - $K_2O\cdot CrO_3$ (II) (Tarapacaite) - 194.20 - Yellow - Rhombic - D 2.732^{18} (A31) - Transition to I 666 (G77) - R.I. α 1.7087, β 1.7261, γ 1.7304 (C54)

Potassium chromate, di- - $K_2O\cdot 2CrO_3$ - 294.21 - Orange Red - Monoclinic, Triclinic - D 2.69 (I8) - M.P. 397.4 (L39) - T.P. 241.6 (L39) - R.I. α 1.7202, β 1.7380, γ 1.8197 (I8)

Potassium chromate, tri- - $K_2O\cdot 3CrO_3$ - 394.22 - Red - Monoclinic - D 2.648^{18} (I8) - M.P. 250 (I8)

Potassium chromate, tetra- - $K_2O\cdot 4CrO_3$ - 494.23 - Red - Monoclinic - D 2.649^{11} (I8) - M.P. 215 (I8)

Potassium chromium (III) fluoride - $3KF\cdot CrF_3$ - 283.30 - D 2.93^{0} (D35)

Potassium chromium (III) phosphate - $K_2O\cdot Cr_2O_3\cdot 2P_2O_5$ - 530.13 - Monoclinic - D 3.5 (I8)

Potassium chromium (VI) selenate - $K_2O\cdot CrO_3\cdot SeO_3$ - 321.16 - M.P. 120 (I8)

Potassium chromium (VI) sulfate - $K_2O\cdot CrO_3\cdot SO_3$ - 274.27 - M.P. 350 (I8)

Potassium cobalt fluoride - $KF\cdot CoF_2$ - 155.036 - X-ray Lines 2.88, 2.03, 4.08 (A40)

Potassium cobalt (II) fluoride - $2KF\cdot CoF_2$ - 213.13 - Monoclinic - D 3.22 (I8)

Potassium columbate - $K_2O\cdot Cb_2O_5$ - 360.01 - Cubic - D 4.634 (X-ray) (Q2) - M.P. > 1000 (W46) - X-ray Lines 2.83, 2.00, 1.64 (A41)

Potassium columbium fluoride - $2KF\cdot CbF_5$ - 304.10 - Monoclinic - D 3.21 (Z33)

Potassium cyanate - KCNO - 81.114 - Colorless - Tetragonal - D 2.056^{20} (C57) - X-ray Lines 2.73, 3.04, 2.53 (A40)

Potassium cyanide - KCN - 65.114 - Colorless - Cubic - D 1.560^{25} (B46) - M.P. 623 (K15) - T.P. -60 (B42) - R.I. 1.410 (W42) - X-ray Lines 3.26, 2.30, 1.97 (A41)

otassium cyanide, seleno- - KCNSe - 144.07 - Needle - D 2.347^{20} (H104) - D.T. 100 (C60)

otassium cyanide, thio- - KCNS (I) - 97.180 - M.P. 176.8 (K75) - X-ray Lines 2.97, 2.79, 2.51 (Form not defined) (A40)

otassium cyanide, thio- - KCNS (II) - 97.180 - Colorless - Rhombic - D 1.882^{20} (H104) - Transition to I 140.6 (K75) - R.I. α 1.532, β 1.660, γ 1.730 (W42)

otassium deuterium phosphate - KD_2PO_4 (I) - 138.10 - Tetragonal - (Q1)

otassium deuterium phosphate - KD_2PO_4 (II) - 138.10 - Orthorhombic - T.P. 273-213 (Q1)

Potassium fluoride - KF - 58.10 - Colorless - Cubic - D 2.505^{25} (W58) - M.P. 846 (M78) - B.P. 1498 (K79) - R.I. 1.36290^{25} (W58) - X-ray Lines 2.69, 1.887, 1.192 (A40)

Potassium fluoride, acid- - $KF \cdot HF$ - 78.10 - Colorless - Tetragonal - D 2.36 (X-ray) (S119) - M.P. 239 (C1) - T.P. 195 (C1) - X-ray Lines 2.59, 2.38, 2.18 (A40)

Potassium fluoride, acid- - $KF \cdot 2HF$ - 98.11 - Colorless - M.P. 71.7 (C1)

Potassium fluoride, acid- - $KF \cdot 3HF$ - 118.12 - Colorless - M.P. 65.8 (C1)

Potassium fluoride, acid- - $KF \cdot 4HF$ - 138.13 - Colorless - M.P. 72.0 (C1)

Potassium fluoride, acid- - $2KF \cdot 5HF$ - 216.23 - Colorless - M.P. 64.3 (C1)

Potassium fluoride, hydrate - $KF \cdot 2H_2O$ - 94.13 - Colorless - Monoclinic - M.P. 41 (F40) - R.I. α 1.345, β 1.352, γ 1.363 (W42) - X-ray Lines 3.01, 2.58, 4.42 (A40)

Potassium formate - $K \cdot HCO_2$ - 84.114 - Colorless - Rhombic - D 1.91 (I8) - M.P. 167.5 (I8)

Potassium gallium oxide, hydrate - $K_2O \cdot Ga_2O_3 \cdot 4H_2O$ - 353.70 - D 2.56 (I18) - R.I. α 1.485, γ 1.509 (I18)

Potassium gallium sulfide - $K_2S \cdot Ga_2S_3$ - 345.90 - Yellow - Tetragonal - M.P. 965 (I18) - R.I. > 1.74 (I18)

Potassium germanate - $K_2O \cdot GeO_2$ - 198.79 - Colorless - D $3.40^{21.5}$ (S40) - M.P. 842 (S38)

Potassium germanate - $K_2O \cdot 2GeO_2$ - 303.39 - Colorless - D $4.31^{21.5}$ (S40) - M.P. 797 (S38)

Potassium germanate - $K_2O \cdot 4GeO_2$ - 512.59 - Colorless - D $4.12^{21.5}$ (S40) - M.P. 1038 (S38)

Potassium germanium fluoride - $2KF \cdot GeF_4$ - 264.80 - White - Hexagonal - D 3.32 (H71) - M.P. 730 (M91) - B.P. 835 (M91)

Potassium hafnium fluoride - $2KF \cdot HfF_4$ - 370.8 - Monoclinic - R.I. α 1.461, β -, γ 1.449 (I8)

Potassium hafnium fluoride - $3KF \cdot HfF_4$ - 428.9 - Cubic - R.I. 1.403 (I8)

Potassium hydroxide - KOH - 56.104 - Colorless - Rhombic, Cubic - D 2.12 (K54) - M.P. 360 (K15) - T.P. 248 (H52) - B.P. 1327 (K13) - R.I. 1.422^{380} (M45) - X-ray Lines 2.69, 1.98, 2.93 (A40)

Potassium iodide - KI - 166.02 - Colorless - Cubic - D 3.123^{25} (I8) - M.P. 686 (K79) - B.P. 1330 (K79) - R.I. 1.6670 (S86) - X-ray Lines 3.53, 2.49, 1.578 (A40)

Potassium iron (II) cyanide - $K_4Fe(CN)_6$ - 368.34 - Yellow - Monoclinic - D 1.935^{25} (B46) - R.I. α 1.5752, β -, γ 1.5815 (G41)

Potassium iron (III) cyanide - $K_3Fe(CN)_6$ - 329.25 - Orange - Monoclinic - D 1.858^{25} (B46) - D.T. 208 (J22) - R.I. α 1.5660, β 1.5689, γ 1.5831 (I8)

Potassium iron (III) fluoride - $3KF \cdot FeF_3$ - 287.14 - Colorless - Cubic - D 2.20 (M55)

Potassium iron (III) oxide - $K_2O \cdot Fe_2O_3$ - 253.89 - D 3.417 (H66) - X-ray Lines 2.80, 1.62, 4.58 (A40)

Potassium iron (III) silicate - $K_2O \cdot Fe_2O_3 \cdot 4SiO_2$ (I) (Iron Leucite) - 494.13 - Yellow - Pseudocubic - D 2.59 (G7) - M.P. 1050 (Incong.) (F4) - R.I. α -, β 1.619, γ - (G7)

Potassium iron (III) silicate - $K_2O \cdot Fe_2O_3 \cdot 4SiO_2$ (II) - 494.13 - Monoclinic - R.I. α -, β 1.80, γ - (G6)

Potassium iron (III) silicate - $K_2O \cdot Fe_2O_3 \cdot 6SiO_2$ (Iron Orthoclase) - 614.25 - Yellow - Monoclinic, Triclinic - M.P. 920 (Incong.) (F4) - R.I. α 1.601, β -, γ 1.609 (G6)

Potassium iron (III) sulfide - $K_2S \cdot Fe_2S_3$ - 318.16 - Hexagonal - D 2.66 (O1)

Potassium iron (III) sulfide - $K_2S \cdot Fe_2S_3$ - 318.16 - Monoclinic (B98)

Potassium lanthanum fluoride - α-$KF \cdot LaF_3$ - 254.02 - Cubic - D 4.06 (Z17) - M.P. 770 (Incong.) (D18)

Potassium lanthanum fluoride - β_1-$KF \cdot LaF_3$ - 254.02 - Hexagonal - D 4.52 (Z17)

Potassium lanthanum silicate - $K_2O \cdot La_2O_3 \cdot 2SiO_2$ - 540.15 - Colorless - Hexagonal - R.I. ω 1.867, ϵ 1.840 (E14)

Potassium lead (II) silicate - $K_2O \cdot PbO \cdot 4SiO_2$ - 557.64 - Rectangular Plate - M.P. 757 (G13) - R.I. α 1.590, β 1.612, γ 1.650 (G13)

Potassium lead (II) silicate - $K_2O \cdot 2PbO \cdot 2SiO_2$ - 660.73 - Hexagonal - D 5.15 (M20) - M.P. 918 (G13) - R.I. ω 1.93, ϵ 1.72 (G13)

Potassium lead (II) silicate - $K_2O \cdot 4PbO \cdot 8SiO_2$ - 1467.51 - Fiber - M.P. 779 (G13) - R.I. α 1.69, β -, γ 1.69 (G13) - X-ray Lines 2.76, 8.1, 3.50 (A46)

Potassium lead (II) silicate - $2K_2O \cdot PbO \cdot 3SiO_2$ - 591.77 - M.P. 735 (G13) - R.I. α 1.665, β -, γ 1.685 (G13)

Potassium lead (II) sulfate - $K_2Pb(SO_4)_2$ (Nat. Palmierite) - 477.53 - Rhombic - R.I. ω 1.712, ϵ - (Z27)

Potassium lithium carbonate - $KLiCO_3$ - 106.046 - M.P. 515 (I8)

Potassium lithium sulfate - $KLiSO_4$ - 142.102 - Hexagonal - D 2.393 (I8) - M.P. 716 (G41) - R.I. ω 1.4715, ϵ 1.4721 (I8) - X-ray Lines 3.94, 3.09, 2.57 (A40)

Potassium lithium tungstate - $K_2O \cdot Li_2O \cdot WO_3$ - 355.99 - M.P. 632 (L49)

Potassium magnesium aluminum silicate, hydrate - $K_2O \cdot 2MgO \cdot Al_2O_3 \cdot 10SiO_2 \cdot 7H_2O$ (Nat. Bondsdorffite) - 1003.48 - Colorless - D 2.65 (P33) - R.I. α 1.563, β 1.568, γ 1.568 (P33)

Potassium magnesium aluminum silicate, hydrate - $K_2O \cdot 6MgO \cdot Al_2O_3 \cdot 6SiO_2 \cdot 2H_2O$ (Phlogopite) - 834.44 - Colorless - Monoclinic - D 2.85 (L18) - R.I. α 1.520, β -, γ 1.558 (G71)

Potassium magnesium borate, hydrate - $K_2O \cdot 4MgO \cdot 11B_2O_3 \cdot 18H_2O$ (Heintzite) - 1345.80 - Monoclinic - D 2.1 (I8) - R.I. α 1.508, β 1.526, γ 1.550 (I8)

Potassium magnesium carbonate - $K_2CO_3 \cdot MgCO_3$ - 222.53 - D 2.671 (E13) - R.I. ω 1.597, ϵ 1.47 (E13)

Potassium magnesium carbonate - $K_2CO_3 \cdot MgCO_3$ (Glass) - 222.53 - Colorless - D 2.390 (E13) - R.I. 1.496 (E13)

Potassium magnesium fluoride - $KF \cdot MgF_2$ - 120.42 - Colorless - Tetragonal - D 2.8 (D34) - M.P. 1080 (R16)

Potassium magnesium fluoride - $2KF \cdot MgF_2$ - 178.51 - Colorless - D 2.7 (I8)

Potassium magnesium phosphate - $K_2O \cdot 2MgO \cdot P_2O_5$ - 316.79 - Rhombic - D 2.6 (I8)

Potassium magnesium sulfate - $K_2Mg_2(SO_4)_3$ (Langbeinite) - 415.03 - Colorless - Cubic - D 2.83 (L18) - M.P. 930 (G61) - R.I. 1.533 (L18)

Potassium manganate, per- - $KMnO_4$ - 158.03 - Purple - Rhombic - D 2.698^{18} (H91) - D.T. $<$ 240 (I8) - R.I. ω 1.59, ε - (I8) - X-ray Lines 3.22, 2.95, 3.57 (A40)

Potassium manganese (II) sulfate - $K_2Mn_2(SO_4)_3$ (Nat. Manganolangbeinite) - 476.25 - Rose Red - Cubic - D 3.02 (L18) - R.I. 1.572 (L18)

Potassium molybdate - $K_2O \cdot MoO_3$ (I) - 238.14 - Colorless - M.P. 919 (K79) - X-ray Lines 3.17, 2.26, 3.03 (Form not defined) (A40)

Potassium molybdate - $K_2O \cdot MoO_3$ (II) - 238.14 - Colorless - Transition to I 480 (H80)

Potassium molybdate - $K_2O \cdot MoO_3$ (III) - 238.14 - Colorless - Transition to II 458 (H80)

Potassium molybdate - $K_2O \cdot MoO_3$ (IV) - 238.14 - Colorless - D 2.91^{18} (B24) - Transition to III 323 (H80)

Potassium molybdate - $K_2O \cdot 2MoO_3$ - 382.09 - M.P. 484 (A15)

Potassium molybdate - $K_2O \cdot 3MoO_3$ - 526.04 - M.P. $\sim$ 560 (H10)

Potassium molybdate - $K_2O \cdot 4MoO_3$ - 669.99 - M.P. $\sim$ 565 (H10)

Potassium neptunium (IV) fluoride - $KF \cdot 2NpF_4$ - Rhombic - D 6.54 (Z17)

Potassium nitrate - KNO_3 (I) - 101.104 - Colorless - Trigonal - D 2.033^{128} (C45) - M.P. 333 (K79) - D.T. 400 (I8) - X-ray Lines 3.77, 3.03, 2.66; 2.60, 1.80, 2.15 (Forms not defined) (A40) (A41)

Potassium nitrate - KNO_3 (II) - 101.104 - Colorless - Rhombic - D 2.098^{18} (H91) - Transition to I 128 (K12) - R.I. α 1.3320, β 1.5038, γ 1.5042 (I8)

Potassium nitrate, acid- - $KNO_3 \cdot 2HNO_3$ - 227.136 - Colorless - M.P. 22 (I8)

Potassium nitrate chloride - $KNO_3 \cdot KCl$ - 175.657 - Colorless - M.P. 360 (Incong.) (R49)

Potassium nitrate, hydroxy- - $KNO_3 \cdot 2KOH$ - 213.312 - Colorless - M.P. 232 (R20)

Potassium nitrite - KNO_2 - 85.104 - Colorless - Monoclinic - D 1.926 (B155) - M.P. 441 (B155) - T.P. 47 (B155) - D.T. 460 (B155) - X-ray Lines 3.31, 2.50, 2.20 (A40)

Potassium oxalate, acid- - KHC_2O_4 - 128.124 - Colorless - Monoclinic - D 2.066 (H38) - R.I. α 1.382, β 1.553, γ 1.573 (H38)

Potassium oxide - K_2O - 94.192 - Colorless - Cubic - D 2.32 (I8) - D.T. 881 (600 m.m.) (L40)

Potassium oxide, per- - K_2O_2 - 110.192 - Colorless or Slight Yellow - M.P. 490 (C19) - D.T. 779 (760 m.m.) (C19)

Potassium oxide, di- - KO_2 - 71.096 - Yellow - Tetragonal - D 2.14 (X-ray)(H35) - M.P. 400 (R12) - X-ray Lines 3.34, 2.87, 2.18 (A41)

Potassium phosphate, meta- - $K_2O \cdot P_2O_5$ - 236.15 - Colorless - D 2.258^{18} (I8) - M.P. 810 (K79) - T.P. 450 (I8) - B.P. 1320 (L56) - X-ray Lines 3.03, 2.75, 2.56 (A40)

Potassium phosphate, pyro- - $2K_2O \cdot P_2O_5$ - 330.34 - Colorless - D 2.33 (I8) - M.P. 1092 (K15) - T.P. 278 (I8)

Potassium phosphate, ortho- - $3K_2O \cdot P_2O_5$ - 424.54 - Colorless - Needle - D 2.564^{17} (H91) - M.P. 1340 (K79)

Potassium phosphate, boro- - $2\,K_2O \cdot B_2O_3 \cdot P_2O_5$ - 399.98 - Colorless - Trigonal - M.P. 855 (K79)

Potassium phosphate, fluo- - $KF \cdot PF_5$ - 184.08 - Cubic - D 2.591^{18}(L14)

Potassium phosphate, hydrate - $K_2O \cdot P_2O_5 \cdot 2H_2O$ - 272.18 - Colorless - Tetragonal - D 2.338 (I8) - M.P. 253 (M43) - R.I. ω 1.5095, ε 1.4684 (I8) - X-ray Lines 2.645, 1.962, 3.755 (A40)

Potassium phosphate, hydrate - $2K_2O \cdot P_2O_5 \cdot H_2O$ - 348.36 - White (R12) - X-ray Lines 2.96, 3.03, 4.26 (A40)

Potassium phosphate, hydrate - $2K_2O \cdot P_2O_5 \cdot 3H_2O$ - 384.39 - Colorless - D 2.33 (R12) - $-2H_2O$ at 180 (R12) - X-ray Lines 2.88, 2.97, 2.76 (A40)

Potassium phosphate, hydrate - $2K_2O \cdot P_2O_5 \cdot 7H_2O$ - 456.46 - Colorless - Monoclinic - D 2.026^{25} (A38) - X-ray Lines 3.43, 2.41, 2.56 (A40)

Potassium phosphate, hydrate - $3K_2O \cdot P_2O_5 \cdot 16H_2O$ - 712.79 - Colorless - Rectangular Plates - M.P. 45.1 (J12)

Potassium platinum (IV) chloride - $2KCl \cdot PtCl_4$ - 486.16 - Yellow - Cubic - D 3.474 (K39) - D.T. 250 (I8) - R.I. 1.827 (5770 A) (W42) - X-ray Lines 5.6, 4.87, 3.44 (A40)

Potassium plutonium (IV) fluoride - $KF \cdot PuF_4$ - 373.18 - Rhombic - D 5.66 (Z17)

Potassium plutonium (IV) fluoride - $KF \cdot 2PuF_4$ - 688.26 - Rhombic - D 6.73 (Z17)

Potassium rhenate - $K_2O \cdot Re_2O_7$ - 578.81 - Black - Tetragonal - D 4.38 (S68) - M.P. 555 (S68) - B.P. 1370 (V15) - R.I. ω 1.643, ε 1.673 (M1)

Potassium selenate - $K_2O \cdot SeO_3$ - 221.15 - Colorless - Rhombic - D 3.066 (I8) - R.I. α 1.5352, β 1.5390, γ 1.5446 (I8) - X-ray Lines 3.00, 4.30, 3.08 (A40)

Potassium selenate sulfate - $K_2O \cdot SeO_3 \cdot SO_3$ - 301.22 - M.P. 12 (I8)

Potassium selenide - K_2Se - 157.15 - Colorless - Cubic - D 2.851 (I8)

Potassium silicate - $K_2O \cdot SiO_2$ - 154.25 - Colorless - Rhombic - M.P. 976 (I8) - T.P. 750, 725 (K79) - R.I. α 1.520, β -, γ 1.528 (K81)

Potassium silicate - $K_2O \cdot 2SiO_2$ - 214.31 - Colorless - Rhombic - D 2.538^{25} (G52) - M.P. 1045 (K82) - T.P. 594 (K82) - R.I. α 1.503, β -, γ 1.513 (K82)

otassium silicate - $K_2O \cdot 2SiO_2$ (Glass) - 214.31 - Colorless - D 2.474^{25} (G52) - R.I. 1.51 ± (M77)

otassium silicate - $K_2O \cdot 4SiO_2$ - 334.43 - Colorless - Monoclinic, Triclinic - D 2.335^{25} (G52) - M.P. 770 (K82) - T.P. 592 (G52) - R.I. α 1.477, β -, γ 1.482 (K81)

otassium silicate - $K_2O \cdot 4SiO_2$ (Glass) - 334.43 - Colorless - D 2.384^{25} (G52) - R.I. 1.495 (G52)

otassium silicate, fluo- - $2KF \cdot SiF_4$ - 220.25 - Colorless - Cubic - D 2.665 (I8) - R.I. 1.3991 (R2) - X-ray Lines 2.35, 2.03, 4.71 (Form not defined) (A40)

otassium silicate, fluo- - $2KF \cdot SiF_4$ - 220.25 - Colorless - Hexagonal - D 3.081 (G56)

otassium silicate, hydrate - $K_2O \cdot SiO_2 \cdot H_2O$ - 172.27 - Colorless - R.I. α -, β 1.50, γ - (M74)

Potassium silicate, hydrate - $K_2O \cdot 2SiO_2 \cdot H_2O$ - 232.33 - Colorless - Granular - R.I. α -, β 1.50, γ - (M74)

Potassium silicate, hydrate - $K_2O \cdot 4SiO_2 \cdot H_2O$ - 352.45 - Rhombic - D 2.417 (I8) - M.P. 515 (M75) - D.T. 400 (I8) - R.I. α 1.495, β 1.535, γ - (I8)

Potassium silicate, hydrate - $2K_2O \cdot 2SiO_2 \cdot H_2O$ - 326.52 - Colorless - Granular - R.I. α -, β $\sim$1.50, γ - (M74)

Potassium silver carbonate - $K_2CO_3 \cdot Ag_2CO_3$ - 413.972 - Rhombic (D29) - D 3.769 (I8)

Potassium sodium aluminum fluoride - $KF \cdot 2NaF \cdot AlF_3$ - 226.06 - M.P. 941 (N5)

Potassium sodium aluminum fluoride - $2KF \cdot NaF \cdot AlF_3$ (Nat. Elpasolite) - 242.16 - Cubic - D 2.995 (F71) - M.P. 952 (N5) - R.I. 1.376 (F71)

Potassium sodium aluminum fluoride - $3KF \cdot 3NaF \cdot 2AlF_3$ - 468.22 - M.P. 948 (N5)

Potassium sodium aluminum fluoride - $9KF \cdot 15NaF \cdot 8AlF_3$ - 1824.58 - M.P. 947 (N5)

Potassium sodium aluminum fluoride - $15KF \cdot 6NaF \cdot 7AlF_3$ - 1711.22 - M.P. 952 (N5)

Potassium sodium aluminum silicate, hydrate - $K_2O \cdot Na_2O \cdot 4Al_2O_3 \cdot 8SiO_2 \cdot 4H_2O$ (Nat. Igalikite) - 1116.49 - Hexagonal - D 2.559 (B84) - R.I. ω > ε, ε 1.540 (B84)

Potassium sodium chromate - $KNaO \cdot CrO_3$ - 178.10 - M.P. 607 (H10)

Potassium sodium chromate - $K_2O \cdot Na_2O \cdot 4CrO_3$ - 556.23 - M.P. 310 (E24)

Potassium sodium sulfate - $3K_2SO_4 \cdot Na_2SO_4$ (Glaserite) - 664.83 - Trigonal - D 2.696 (I8) - M.P. < 1000 (I8) - T.P. 431 (N1) - R.I. ω 1.4901, ε 1.4996 (I8)

Potassium strontium phosphate - $K_2O \cdot SrO \cdot P_2O_5$ - 339.78 - Colorless - Hexagonal - D 2.9 (I8)

Potassium strontium phosphate - $K_2O \cdot 2SrO \cdot P_2O_5$ (I) - 443.41 - Colorless - Tetragonal - D 3.98 (X-ray) (K41) (S119)

Potassium strontium phosphate - $K_2O \cdot 2SrO \cdot P_2O_5$ (II) - 443.41 - Colorless - Hexagonal - D 2.90 (X-ray) (K41) (S119)

Potassium sulfate - K_2SO_4 (I) - 174.258 - Colorless - Hexagonal - M.P. 1069.1 (R33) - B.P. 1700 (L56)

Potassium sulfate - K_2SO_4 (II) - 174.258 - Colorless - Rhombic - D 2.662 (I8) - Transition to I 583 (R33) - R.I. α 1.49333, β 1.49456, γ 1.49733 (W58) (All at 20°) - X-ray Lines 2.89, 3.01, 2.08 (Form not defined) (A40)

Potassium sulfate - $K_2O \cdot 2SO_3$ - 254.324 - Colorless - Prism - D 2.512^{28} (C5) - M.P. 414.2 (C5) - T.P. 225, 315 (C5) - X-ray Lines 3.23, 3.07, 2.90 (A40)

Potassium sulfate - $K_2O \cdot 3SO_3$ - 334.390 - Colorless - D.T. 150 (B17)

Potassium sulfate, acid- - $KHSO_4$ (Misenite) - 136.170 - Colorless - Rhombic, Monoclinic - D 2.35 (I8) - M.P. 218.6 (K23) - T.P. 182, 202 (K23) - R.I. α 1.475, β 1.480, γ 1.488 (L18) - X-ray Lines 3.85, 3.40, 3.01 (A40)

Potassium sulfate, acid- - $K_3H(SO_4)_2$ - 310.428 - Colorless - Monoclinic - D 2.59^{18} (I8) - R.I. α 1.479, β 1.490, γ 1.526 (I8)

Potassium sulfate, acid- - KHS_2O_7 - 216.236 - Colorless - M.P. 168 (I8)

Potassium sulfide - K_2S - 110.258 - Colorless - Cubic - D 1.74 (Z43) - M.P. 912 (G59) - T.P. 146.4 (I8) - X-ray Lines 2.60, 1.84, 1.51 (A41)

Potassium sulfide, di- - K_2S_2 - 142.324 - Reddish Yellow - M.P. 470 (T26)

Potassium tantalate - $K_2O \cdot Ta_2O_5$ - 535.95 - Cubic - D 7.022 (X-ray) (Q2) - X-ray Lines 2.81, 1.78, 1.63 (A41)

Potassium tantalum fluoride - $2KF \cdot TaF_5$ - 392.07 - Colorless - Monoclinic (H70) - D 4.56 (I8) - X-ray Lines 3.44, 5.3, 5.1 (A40)

Potassium tantalum silicate - $8K_2O \cdot Ta_2O_5 \cdot 16SiO_2$ (Glass) - 2156.26 - Colorless - D 2.885 (S118) - R.I. 1.541 (S118)

Potassium telluride - K_2Te - 205.80 - Colorless - Cubic - D 2.52 (Z43)

Potassium tellurite - $K_2O \cdot TeO_2$ - 253.80 - X-ray Lines 3.17, 2.75, 9.7 (A40)

Potassium thorium (IV) fluoride - $KF \cdot ThF_4$ - 366.22 - Rhombohedral - D 5.10 (Z17) - M.P. 906 (D18)

Potassium thorium (IV) fluoride - $KF \cdot 2ThF_4$ - 674.34 - Rhombic - D 6.04 (Z17)

Potassium thorium (IV) fluoride - $KF \cdot 3ThF_4$ - 982.46 - M.P. 960 (D17)

Potassium thorium (IV) fluoride - $KF \cdot 6ThF_4$ - 1906.82 - Hexagonal - D 6.25 (Z17)

Potassium thorium (IV) fluoride - α-$2KF \cdot ThF_4$ - 424.32 - Cubic - D 4.33 (Z17)

Potassium thorium (IV) fluoride - β-$2KF \cdot ThF_4$ - 424.32 - Hexagonal - D 4.91 (Z17)

Potassium thorium (IV) fluoride - $3KF \cdot ThF_4$ - 482.42 - M.P. 870 (D17)

Potassium thorium (IV) fluoride - $5KF \cdot ThF_4$ - 598.62 - Rhombic - D 3.58 (Z17)

Potassium thorium phosphate - $K_2O \cdot 4ThO_2 \cdot 3P_2O_5$ - 1576.55 - Colorless - Prismatic - D 5.75^{12} (M29)

Potassium titanium fluoride, hydrate - $2KF \cdot TiF_4 \cdot H_2O$ - 219.01 - X-ray Lines 2.18, 3.39, 2.85 (A40)

Potassium titanate - $K_2O \cdot TiO_2$ - 174.09 - M.P. 810 (K15) - X-ray Lines 2.76, 2.32, 2.18 (A40)

Potassium titanate - $K_2O \cdot 2TiO_2$ - 253.99 - Rhombic - D 3.485 (B10) - M.P. 980 (I8) - R.I. α -, $\beta > 1.74$, γ - (N27)

Potassium titanium fluoride - $2KF \cdot TiF_4$ - 240.09 - Trigonal - D 3.012^{18} (Z33) - M.P. 780 (G31) - R.I. ω 1.475, $\varepsilon < \omega$ (Z33)

Potassium tungstate - $K_2O \cdot WO_3$ - 326.11 - Colorless - Monoclinic - D 3.120^{001} (I8) - M.P. 927 (K15) - T.P. 338 (H80)

Potassium tungstate - $K_2O \cdot 2WO_3$ - 558.03 - M.P. 555 (I8)

Potassium tungstate - $K_2O \cdot 8WO_3$ - 1949.55 - Steel Gray - D 6.53 (I8)

Potassium uranium (IV) fluoride - $KF \cdot UF_4$ - 372.17 - Rhombic - D 5.38 (Z17)

Potassium uranium (IV) fluoride - $KF \cdot 2UF_4$ - 686.24 - Rhombic - D 6.49 (Z17)

Potassium uranium (IV) fluoride - $KF \cdot 3UF_4$ - 1000.31 - Rhombic - D 6.64 (Z17)

Potassium uranium (IV) fluoride - $KF \cdot 6UF_4$ - 1942.52 - Hexagonal - D 6.73 (Z17)

Potassium uranium (IV) fluoride - β_2-$2KF \cdot UF_4$ - 430.27 - Hexagonal - D 4.77 (Z17)

Potassium uranium (IV) fluoride - α-$2KF \cdot UF_4$ - 430.27 - Cubic - D 4.53 (Z17)
Potassium uranium (IV) fluoride - β-$2KF \cdot UF_4$ - 430.27 - Hexagonal - D 5.10 (Z17)
Potassium uranium (IV) fluoride - α-$3KF \cdot UF_4$ - 488.36 - Cubic - D 4.12 (Z17)
Potassium uranium (IV) fluoride - α^1-$3KF \cdot UF_4$ - 488.36 - Tetragonal - D 4.13 (Z17)
Potassium uranium (VI) oxide - $K_2O \cdot UO_3$ - 380.26 - Orange-Yellow (R12) - Rhombic - X-ray Lines 7.5, 3.20, 3.55 (A40)
Potassium uranium (VI) sulfate, hydrate - $K_2O \cdot UO_3 \cdot 2SO_3 \cdot 2H_2O$ - 576.43 - Yellow - Monoclinic - D $3.363^{19.1}$ (R12) - $-2H_2O$ at 120 (R12) - R.I. α 1.5144, β 1.5266, γ 1.567-1.571 (5800A) (L12)
Potassium uranyl nitrate - $K_2(UO_2)(NO_3)_4$ - 596.29 - Green - Monoclinic - D 3.36 (N22) - R.I. α 1.5349, β -, γ 1.5422 (N22)
Potassium vanadate - $K_2O \cdot V_2O_5$ - 276.09 - Pale Yellow - M.P. 515 (M16) - X-ray Lines 3.11, 2.82, 2.60 (A40)
Potassium yttrium fluoride - $3KF \cdot YF_3$ - 320.22 - M.P. 996 (D18)
Potassium zinc chloride - $2KCl \cdot ZnCl_2$ - 285.40 - Colorless - D 2.364, (K58)
Potassium zinc silicate - $K_2O \cdot ZnO \cdot SiO_2$ - 235.63 - Cubic - M.P. 1300 (Incong.) (I6) - R.I. 1.622 (I6)
Potassium zinc uranyl acetate, hydrate - $KZn(UO_2)_3(CH_3CO_2)_9 \cdot 6H_2O$ - 1554.18 - Tetragonal - R.I. ω 1.477, ε 1.487 (I7a)
Potassium zirconium fluoride - $2KF \cdot ZrF_4$ - 283.41 - Colorless - Monoclinic - D 3.58 (K27) - R.I. α 1.454, β 1.465, γ 1.498 (K27)
Potassium zirconium fluoride - $3KF \cdot ZrF_4$ - 341.51 - Cubic - D 3.17 (X-ray) (S119) - R.I. 1.408 (M78)

Praseodymium - Pr - 140.92 - Hexagonal - D 6.63^{20} (A20) - M.P. 940 (K79) (A20) - X-ray Lines 2.97, 1.55, 2.58 (A41)
Praseodymium chloride - $PrCl_3$ - 247.29 - Bluish Green - Needle, Hexagonal - D 4.15^{25} (K37) - M.P. 823 (K37) - B.P. > 1000 (V13)
Praseodymium fluoride - PrF_3 - 197.92 - Yellow - Hexagonal - D 6.33 (X-ray) (O7) - M.P. 1370 (W13)
Praseodymium hydroxide - $Pr(OH)_3$ - 191.94 - Hexagonal - D 4.74 (X-ray) (F57)
Praseodymium molybdate - $Pr_2O_3 \cdot 3MoO_3$ - 761.69 - Grass Green - Tetragonal - D 4.84^{17} (M29) - M.P. 1030 (M29) - R.I. ω -, ε 2.007 (5700A) (Z29)
Praseodymium nitrate, hydrate - $Pr(NO_3)_3 \cdot 6H_2O$ - 435.04 - Green - Triclinic - M.P. 56 (Incong.) (F67)
Praseodymium oxide - Pr_2O_3 - 329.84 - Yellow - Hexagonal, Trigonal - D 6.94^{20} (P68)
Praseodymium oxide - Pr_4O_7 - 675.68 - D 6.715 (I8)
Praseodymium oxide - Pr_6O_{11} - 1021.52 - Dark Brown - D 6.61^{20} (P68) - D.T. 500-600 (F34)
Praseodymium oxide - $Pr_{10}O_{18}$ - 1697.20 - D 6.704 (I8)
Praseodymium (IV) oxide - PrO_2 - 172.92 - Black - D 6.82^{20} (P68) - D.T. > 350 (P68)
Praseodymium phosphate - $Pr_2O_3 \cdot P_2O_5$ (I) - 471.80 - Monoclinic (M67) - D 5.344 (X-ray) (M67)

Praseodymium phosphate - $Pr_2O_3 \cdot P_2O_5$(II) - 471.80 - Hexagonal (M67)
Praseodymium selenate - $Pr_2O_3 \cdot 3SeO_3$ - 710.72 - D 4.30^{15} (I8)
Praseodymium selenate, hydrate - $Pr_2O_3 \cdot 3SeO_3 \cdot 8H_2O$ - 854.85 - D 3.094^{14} (I8)
Praseodymium selenide - Pr_2Se_3 - 518.72 - Red - D 6.48 (K48)
Praseodymium (IV) selenide - Pr_2Se_4 - 597.68 - D 6.64 (K48)
Praseodymium silicate - $Pr_2O_3 \cdot SiO_2$ - 389.90 - Green (S95)
Praseodymium sulfate - $Pr_2(SO_4)_3$ - 570.04 - Light Green - D 3.720^{16} (I8) - D.T. 1010 (P13)
Praseodymium sulfate, hydrate - $Pr_2(SO_4)_3 \cdot 5H_2O$ - 660.12 - Monoclinic - D 3.173 (I8)
Praseodymium sulfate, hydrate - $Pr_2(SO_4)_3 \cdot 8H_2O$ - 714.17 - Green - Monoclinic - D 2.813^{20} (H54) - M.P. 75 (M29) - $-8H_2O$ at 450 (P13) - R.I. α 1.5399, β 1.5494, γ 1.5607 (I8)
Praseodymium sulfide - Pr_2S_3 - 378.04 - Chocolate-Brown - D 5.25^{25} (K49)

[*] Prometheum - 61 Pm - Synthetic element with mass numbers 147, 148 and 149 for the known isotopes (S45)

Promethium - See Prometheum

Protactinium - See Protoactinium

[**]Protoactinium - Pa - 231 - M.P. 3000 (A20)

Radium - Ra - 226.05 - Brilliant White - D 5.0^{20} (A20) - M.P. 700 (A20) - B.P. 1140 (A20)
Radium beryllium fluoride - $RaF_2 \cdot BeF_2$ - 311.07 - White (B125a) - Rhombic
Radium chloride - $RaCl_2$ - 296.96 - Bluish Violet - Monoclinic - D 4.91 (I8) - M.P. 1000 (I8)
Radium fluoride - RaF_2 - 264.05 - Cubic - D 6.75 (X-ray) (S29)

Rhenium - Re - 186.31 - Hexagonal - D 20^{20} (A20) - M.P. 3170 (A20) - B.P. 5870 (A20) - X-ray Lines 2.10, 2.38, 2.22 (A40)
Rhemium (IV) fluoride - ReF_4 - 262.31 - Dark Green - D 5.383^{20} (R78) - M.P. 124.5 (R78)
Rhemium (VI) fluoride - ReF_6 - 300.31 - Pale Yellow - D $3.616^{18.8}$ (R78) - M.P. 18.8 (R78) - B.P. 47.6 (R78)
Rhemium (VI) fluoride oxide - ReF_2O_2 - 256.31 - Colorless - B.P. 156 (R78)
Rhemium (VI) fluoride oxide - ReF_4O - 278.31 - Colorless - Triclinic - D $3.717^{39.7}$ (Liquid) (R78) - M.P. 39.7 (R78) - B.P. 62.7 (R78)
Rhemium (IV) oxide - ReO_2 - 218.31 - Black - D 11.4 (B48) - D.T. 1000 (B48)
Rhemium (VI) oxide - ReO_3 - 234.31 - Pale Yellow - Cubic - D 7.43 (X-ray) (M25)

---

[*] By action of the International Union of Chemistry, Amsterdam, Holland, September 9, 1949, the official name is promethium.

[**] By action of the International Union of Chemistry, Amsterdam, Holland, September 9, 1949, the official name is protactinium.

Rhemium (VII) oxide - Re_2O_7 - 484.62 - Yellow - D 8.2^{20} (N31) - M.P. 296 (K15) - B.P. 362.4 (K13)
Rhemium (VIII) oxide - Re_2O_8 - 500.62 - Colorless - Globular - D 8.4 (N31) - M.P. 147 (K15)
Rhemium (IV) sulfide - ReS_2 - 250.44 - Black - D 7.506^{25} (J41)
Rhemium (VII) sulfide - Re_2S_7 - 597.08 - Black - D 4.866^{28} (B72)

Rhodium - Rh - 102.91 - Silvery White - Cubic - D 12.44^{20} (A20) - M.P. 1966 (A20) - B.P. 4500 (A20) - X-ray Lines 2.200, 1.150, 1.908 (A40)
Rhodium (III) fluoride - RhF_3 - 159.91 - Red - Trigonal, Hexagonal - D 5.38 (R69) - X-ray Lines 1.66, 3.59, 2.65 (A41)
Rhodium (III) oxide - Rh_2O_3 - 253.82 - Grayish Black - D 8.20 (X-ray) (Z7)
Rhodium (III) sulfide - Rh_2S_3 - 302.02 - Black - D 6.40 (J43)
Rhodium (IV) sulfide - RhS_2 - 167.04 - Cubic - D 6.41 (X-ray) (S119)
Rhodium (V) sulfide - Rh_2S_5 - 366.15 - Dark Gray - D 5.00 (J43)

Rubidium - Rb - 85.48 - White - Cubic - D 1.53^{20} (A20) - M.P. 39 (A20) - B.P. 680 (A20)
Rubidium aluminum fluoride - $RbF \cdot AlF_3$ - 188.45 - X-ray Lines 3.14, 2.37, 1.81 (A41)
Rubidium aluminum fluoride - $3RbF \cdot AlF_3$ - 397.41 - Colorless - M.P. 985 (I8)
Rubidium aluminum silicate - $Rb_2O \cdot Al_2O_3 \cdot 2SiO_2$ - 409.02 - Colorless - Hexagonal - R.I. ω 1.530, ε 1.526 (E14)
Rubidium antimonate, fluo- - $RbF \cdot SbF_5$ - 321.24 - Colorless - Rhombohedral, prismatic needles - D 3.955^{20} (L13) - M.P. 340 (L13) - R.I. $\omega \sim 1.394$, $\varepsilon \sim 1.399$ (L13)
Rubidium beryllium fluoride - $2RbF \cdot BeF_2$ - 255.98 - Colorless - D 3.243^{30} (R10)
Rubidium borate, fluo- - $RbF \cdot BF_3$ - 172.30 - Colorless - Rhombic - D 2.820 (Z24) - M.P. 590 (B83) - D.T. 1000 (600 m.m.) (B83)
Rubidium calcium sulfate - $Rb_2SO_4 \cdot 2CaSO_4$ - 539.33 - M.P. 1043 (K79)
Rubidium carbonate - Rb_2CO_3 - 230.97 - Colorless - M.P. 837 (I8)
Rubidium carbonate, bi- - $RbHCO_3$ - 146.50 - Colorless - Rhombic - D.T. 179 (760 m.m.) (K14)
Rubidium chlorate, per- - $RbClO_4$ - 184.94 - Rhombic - D 3.02 (X-ray) (S119) - X-ray Lines 3.84, 2.72, 2.32 (about 300° c) (A41)
Rubidium chloride - RbCl - 120.94 - Colorless - Cubic - D 2.8032^{25} (W59) - M.P. 715 (K79) - T.P. 20 (W2) - B.P. 1385 (K79) - R.I. 1.49374^{25} (W58) - X-ray Lines 3.29, 2.32, 3.80 (A40)
Rubidium chromate - $Rb_2O \cdot CrO_3$ - 286.97 - Yellow - Rhombic - D 3.52 (S66) - R.I. α -, β 1.71, γ 1.72 (W42)
Rubidium chromate, di- - $Rb_2O \cdot 2CrO_3$ - 386.98 - Triclinic, Monoclinic - D 3.1 (R12) - R.I. $\omega > 1.95$, ε 1.70 (T2)
Rubidium cyanate, thio- - RbSCN - 143.56 - M.P. 195 (I8)
Rubidium fluoride - RbF - 104.48 - Colorless - Cubic - D 3.557 (H43) - M.P. 775 (W20) - B.P. 1410 (K79) - R.I. 1.396 (W42) - X-ray Lines 3.69, 2.61, 1.639 (A40)
Rubidium fluoride, acid- - $RbF \cdot HF$ - 124.49 - Colorless - M.P. 205 (P70)

Rubidium formate - $Rb\cdot HCO_2$ - 130.50 - Colorless - Plates - M.P. 170 (S54)

Rubidium gallium sulfide - $Rb_2S\cdot Ga_2S_3$ - 438.66 - Yellow Brown - Tetragonal - D 3.42 (I18) - M.P. 960 (I18) - R.I. 1.78 (I18)

Rubidium hydroxide - $RbOH$ - 102.49 - Colorless - D 3.203^{11} (I8) - M.P. 301 (H52) - T.P. 245 (H52)

Rubidium iron (III) fluoride - $3RbF\cdot FeF_3$ - 426.29 - Cubic - D $\sim$ 2.6 (M56)

Rubidium lanthanum fluoride - $RbF\cdot LaF_3$ - 300.40 - M.P. 684 (Incong.) (D18)

Rubidium lithium nitrate - $RbLi(NO_3)_2$ - 216.44 - M.P. 191 (P74)

Rubidium magnesium fluoride - $RbF\cdot MgF_2$ - 166.80 - Colorless - M.P. 881 (R16)

Rubidium magnesium fluoride - $2RbF\cdot MgF_2$ - 271.28 - Colorless - M.P. 784 (R16)

Rubidium manganate, per- - $RbMnO_4$ - 204.41 - D 3.235^{10} (I8) - D.T. 259 (C58)

Rubidium nitrate - $RbNO_3$ - 147.49 - Colorless - Hexagonal - D 3.112^{20} (H7) - M.P. 305 (K15) (P74) (R48) - T.P. 160.5, 216, 290 - R.I. α 1.51, β 1.52, γ 1.524 (I8) - X-ray Lines 3.02, 3.85, 2.71 (A40)

Rubidium nitrate, acid- - $RbNO_3\cdot HNO_3$ - 210.50 - Colorless - Tetragonal - M.P. 62 (I8)

Rubidium nitrate, acid- - $RbNO_3\cdot 2HNO_3$ - 273.52 - Colorless - M.P. 45 (I8)

Rubidium oxalate, acid- - $RbHC_2O_4$ - 174.51 - Colorless - Monoclinic - D 2.549 (H38) - R.I. α 1.386, β 1.555, γ 1.583 (H38)

Rubidium oxide - Rb_2O - 186.96 - Pale Yellow - Cubic - D 3.72 (I8) - D.T. 400 (I8) - X-ray Lines 3.37, 2.38, 1.51 (A41)

Rubidium oxide, per- - Rb_2O_2 - 202.96 - Yellow - Cubic - D 3.65 (I8) - M.P. 570 (C19) - D.T. 1011 (760 m.m.) (C19)

Rubidium oxide, di- - RbO_2 - 117.48 - Yellow - Tetragonal - D 3.06 (X-ray) (H35) - M.P. 280 (R12) - X-ray Lines 3.00, 3.67, 3.51 (A41)

Rubidium phosphate, fluo- - $RbF\cdot PF_5$ - 230.46 - Plates - D 3.057^{10} (L14)

Rubidium plutonium (IV) fluoride - $RbF\cdot PuF_4$ - 419.56 - Rhombic - D 5.88 (Z17)

Rubidium rhenate - $Rb_2O\cdot Re_2O_7$ - 671.58 - Rhombic - D 4.73 (S68) - D.T. 598 (S68)

ubidium selenate - $Rb_2O\cdot SeO_3$ - 313.92 - Rhombic - D 3.90 (I8) - R.I. α 1.5515, β 1.5537, γ 1.5582 (I8)

ubidium selenide - Rb_2Se - 249.92 - D.T. 640 (In Vacuum) (B38)

ubidium silicate - $Rb_2O\cdot 2SiO_2$ - 307.08 - M.P. 1155 (D7)

ubidium silicate - $Rb_2O\cdot 4SiO_2$ - 427.20 - M.P. 955 (D7)

ubidium silicate, fluo- - $2RbF\cdot SiF_4$ - 313.02 - Hexagonal - D 3.332^{20} (I8)

ubidium sulfate - Rb_2SO_4 (I) - 267.03 - Hexagonal - D 2.529^{1100} (I8) - M.P. 1060 (K79) - B.P. 1710 (L56) - X-ray Lines 2.98, 3.10, 2.16 (Form not defined) (A40)

ubidium sulfate - Rb_2SO_4 (II) - 267.03 - Colorless - Rhombic - D 3.613 (I8) - Transition to I 653 (I8) - R.I. α 1.5151, β 1.5133, γ 1.5144 (I8)

Rubidium sulfate, bi- - $RbHSO_4$ - 182.55 - Colorless - Rhombic - D 2.892^{18} (I8) - R.I. α -, β 1.473, γ - (W42)
Rubidium sulfide - Rb_2S - 203.03 - Colorless to Pale Yellow - Cubic - D 2.912 (I8)
Rubidium sulfide, di- - Rb_2S_2 - 235.09 - Dark Red - M.P. $\sim$ 420 (B75)
Rubidium thorium (IV) fluoride - $RbF \cdot ThF_4$ - 412.60 - M.P. 852 (D18)
Rubidium thorium (IV) fluoride - $RbF \cdot 3ThF_4$ - 1032.84 - M.P. 1004 (D18)
Rubidium thorium (IV) fluoride - $3RbF \cdot ThF_4$ - 621.56 - M.P. 974 (D18)
Rubidium titanate - $Rb_2O \cdot 2TiO_2$ - 346.76 - D 3.888 (B10)
Rubidium titanium fluoride - $2RbF \cdot TiF_4$ - 332.86 - M.P. 750 (G31)
Rubidium tungstate - $Rb_2O \cdot WO_3$ - 418.88 - Colorless - M.P. 959 - T.P. 516, 501 (S88) - D.T. 900 (S88)
Rubidium yittrium fluoride - $3RbF \cdot YF_3$ - 459.36 - M.P. 1064 (D18)

Ruthenium - Ru - 101.7 - Gray - Hexagonal - D 12.2^{20} (A20) - M.P. 2500 (K79) - T.P. 1035, 1200, 1500 (K79) - B.P. 4900 (A20) - X-ray Lines 2.040, 1.343, 1.139 (A40)
Ruthenium (III) chloride - $RuCl_3$ - 208.1 - Black - Trigonal, Hexagonal - D 3.11 (R15)
Ruthenium (V) fluoride - RuF_5 - 196.7 - Dark Green - D 2.963^{17} (R81) - M.P. 101 (R81) - B.P. 270 (R68)
Ruthenium (IV) oxide - RuO_2 - 133.7 - Deep Blue - Tetragonal - D 7.2 (I8) - X-ray Lines 1.65, 3.13, 2.52 (A41)
Ruthenium (VIII) oxide - RuO_4 - 165.7 - Yellow and Brown - Rhombic - D 3.29^{21} (K93) - M.P. 25.5 (I8) - B.P. 101 (183 m.m.) (I8)
Ruthenium (III) sulfide - Ru_2S_3 (Nat. Laurite) - 299.6 - Cubic - D 6.99 (I8)
Ruthenium (IV) sulfide - RuS_2 - 165.8 - Light Gray - Cubic - D 6.145 (J44)

Samarium - Sm(orSa) - 150.43 - D 6.93^{25} (B94) - M.P. > 1300 (A20)
Samarium borate - $Sm_2O_3 \cdot B_2O_3$ - 418.50 - D 6.05 (I8)
Samarium (II) chloride - $SmCl_2$ - 221.34 - Brownish Red - D 4.56 (K51) - X-ray Lines 2.74, 2.24, 2.19
Samarium chloride - $SmCl_3$ - 256.80 - Faint Yellow - Prism - D 4.30^{25} (K37) - M.P. 677 (K51)
Samarium fluoride - SmF_3 - 207.43 - Hexagonal - D 6.83 (X-ray) (O7)
Samarium formate - $Sm(HCO_2)_3$ - 285.48 - D 3.733 (I8)
Samarium hydroxide - $Sm(OH)_3$ - 201.45 - Pale Yellow - Hexagonal - D 5.37 (X-ray) (F57)
Samarium molybdate - $Sm_2O_3 \cdot 3MoO_3$ - 780.71 - Violet - Tetragonal - D 5.36 (M29)
Samarium nitrate, hydrate - $Sm(NO_3)_3 \cdot 6H_2O$ - 444.55 - Yellow - Triclinic - D 2.375 (I8) - M.P. 78-79 (D13)
Samarium oxide - Sm_2O_3 - 348.86 - Yellowish White - Cubic, Rhombic, Trigonal - D 7.43 (I8)
Samarium phosphate - $Sm_2O_3 \cdot P_2O_5$ - 490.82 - D 5.83^{18} (M29)
Samarium phosphate - $Sm_2O_3 \cdot 5P_2O_5$ - 1058.66 - D 3.487^{20} (M29)
Samarium selenide - Sm_2Se_3 - 537.74 - Gray Black - D 7.10 (K48)
Samarium silicate - $Sm_2O_3 \cdot SiO_2$ - 408.92 - Hexagonal, Monoclinic (G34)
Samarium silicate - $Sm_2O_3 \cdot 2SiO_2$ - 468.98 - Monoclinic (G34)

Samarium sulfate - $Sm_2(SO_4)_3$ - 589.06 - Yellowish White - D 3.898 (P13) - D.T. 989 (719 m.m.) (P13)
Samarium sulfate, hydrate - $Sm_2(SO_4)_3\cdot 8H_2O$ - 733.19 - Yellow - Monoclinic - D 2.957^{20} (H53) - $-8H_2O$ at 400 (P13) - R.I. α 1.5427, β 1.5519, γ 1.5629 (I8)
Samarium sulfide - Sm_2S_3 - 397.06 - Brownish Yellow - D 5.85^{25} (K50) - M.P. 1900 (In Vacuum) (P46)
Samarium titanate - $Sm_2O_3\cdot 2TiO_2$ - 428.76 - Cubic (G33)

Scandium - Sc - 45.10 - Cubic - D 2.5^{20} (A20) - M.P. 1200 (A20) - B.P. 2430 (A20)
Scandium borate - $Sc_2O_3\cdot B_2O_3$ - 207.84 - Hexagonal - D 3.451 (X-ray) (G46)
Scandium chloride - $ScCl_3$ - 151.47 - Colorless - D 2.39^{25} (K42) - M.P. 960 (F24) - B.P. 967 (F24)
Scandium fluoride - ScF_3 - 102.10 - Colorless - Hexagonal - D 2.52 (N38)
Scandium formate - $Sc(HCO_2)_3$ - 180.15 - Colorless - D 1.91 (S96) - R.I. α 1.575, β -, γ 1.631 (S96)
Scandium hydroxide - $Sc(OH)_3$ - 96.124 - Colorless - Cubic - D 2.68 (F57) - D.T. 250 (F57)
Scandium nitrate - $Sc(NO_3)_3$ - 231.12 - Colorless - D.T. 150 (I8)
Scandium nitrate, hydrate - $Sc(NO_3)_3\cdot 4H_2O$ - 303.19 - Colorless - Prismatic - D.T. 100 (I8)
Scandium oxide - Sc_2O_3 - 138.20 - Colorless - D 3.864 (I8)
Scandium selenate - $Sc_2O_3\cdot 3SeO_3$ - 519.08 - Tetragonal - D 3.27 (T53)
Scandium selenide - Sc_2Se_3 - 327.08 - Reddish Violet - D ~ 4.52 (K48)
Scandium silicate - $Sc_2O_3\cdot 2SiO_2$ (Nat. Thortveitite) - 258.32 - Rhombic - D 3.57 (I8) - R.I. α 1.757, β 1.78, γ 1.803 (I8)
Scandium sulfate - $Sc_2(SO_4)_3$ - 378.40 - Colorless - D 2.579 (I8) - D.T. 550 (M29)
Scandium sulfide - Sc_2S_3 - 186.40 - Yellow - D 2.90^{25} (K49)

Selenium - Se - 78.96 - Dark Red or Gray - Hexagonal - D 4.7924$^{20.4}$ (C9) - M.P. 220 (A20) - B.P. 684.8 (S46) - R.I. ω 3.0, ε 3.17 (6800A) (I8) - X-ray Lines 3.01, 3.77, 2.07 (Hexagonal) (A40); 1.430, 1.079, 1.502 (Rhombohedral) (A40)
Selenium - Se (Glass) - 78.96 - Dark Red - D 4.2524$^{21.3}$ (C9) - R.I. 2.92 (W42)
Selenium (IV) fluoride - SeF_4 - 154.96 - Colorless Liquid - D 2.77 (P69) - M.P. -13.2 (P69) - B.P. 93 (P69)
Selenium (VI) fluoride - SeF_6 - 192.96 - Colorless - D 3.27$^{-34.8}$ (Solid), 2.26$^{-34.8}$ (Liquid) (K46) - M.P. -34.8 (K46) - S.P. -45.8 (K46)
Selenium (IV) fluoride oxide - SeF_2O - 132.96 - D 2.67 (P69) - M.P. 4.6 (P69) - B.P. 124 (P69)
Selenium (IV) oxide - SeO_2 - 110.96 - Colorless - Tetragonal - D 3.593 (H84) - M.P. 340 (I8) - S.P. 317 (I8) - R.I. ω > 1.76, ε > ω (B137)
Selenium (VI) oxide - SeO_3 - 126.96 - Pale Yellow - D 3.6 (M29) - D.T. 120 (M29)

Selenium (IV) oxide, hydrate - $SeO_2 \cdot H_2O$ - 128.98 - Colorless - Hexagonal - D 3.004^{18} (I8) - M.P. 70 (Incong.) (I12)

Selenium (VI) oxide, hydrate - $SeO_3 \cdot H_2O$ - 144.98 - Colorless - Hexagonal - D 2.950^{18} (I8) - M.P. 58 (I8)

Selenium (VI) oxide, hydrate - $SeO_3 \cdot 2H_2O$ - 162.99 - Colorless - Needles - D 2.627^{18} (I8) - M.P. 26 (K79) - B.P. 205 (M29)

Selenium (VI) oxide, hydrate - $SeO_3 \cdot 5H_2O$ - 217.04 - M.P. -51.7 (K79)

Selenium (II) sulfide - SeS - 111.03 - Orange Yellow - D 3.056 (R12) - D.T. 118-9 (R12) - X-ray Lines 3.77, 3.22, 4.42 (A41)

Silicon - Si - 28.06 - Graphite Black - Cubic - D 2.33^{20} (A20) - M.P. 1430 (A20) - B.P. 2300 (A20) - X-ray Lines 3.13, 1.93, 1.64 (A40)

Silicon carbide - SiC - 40.07 - Hexagonal, Trigonal - D 3.17 (I8) - M.P. ∼ 2230 (M29) - B.P. 2340 (R67) - R.I. ω 2.654, ε 2.697 (I8) - X-ray Lines 2.51, 1.54, 1.310 (Form not defined) (A40); .84, .89, 1.54 (α-form) (A41); 2.51, .84, .89 (β-form) (A41)

Silicon carbide - SiC - 40.07 - D 3.216 (T22) - R.I. 2.63 (Red) (T22)

Silicon carbide - SiC (A) - 40.07 - Greenish Yellow - Hexagonal - D 3.217 (X-ray) (T22) - R.I. ω 2.6467, ε 2.691 (T22) - X-ray Lines 0.838, 1.54, 1.311 (T22)

Silicon carbide - SiC (B) - 40.07 - Blue - Hexagonal - D 3.218 (T22) - R.I. ω 2.648, ε 2.690 (T22) - X-ray Lines 0.837, 0.888, 1.54 (T22)

Silicon carbide - SiC (C) - 40.07 - Black - Hexagonal - D 3.217 (X-ray) (T22) - X-ray Lines 0.863, 0.803, 0.837 (T22)

Silicon carbide - SiC (D) - 40.07 - Greenish Yellow - Hexagonal - D 3.217 (X-ray) (T22) - X-ray Lines 2.53, 0.837, 1.54 (T22)

Silicon carbide - SiC (F) - 40.07 - Bluish Black - Hexagonal - D 3.217 (X-ray) (T22) - X-ray Lines 2.53, 1.54, 0.838 (T22)

Silicon halogenides - See Silicon, Organo-Compounds of

Silicon oxide, mono- - SiO - 44.06 - Bright Brown (Z42) - Cubic (Z42) - D 2.146 (G11) - B.P. 1990 (Calc.) (G11)

Silicon oxide - SiO_2 (Low Cristobalite) - 60.06 - Colorless - Tetragonal - D 2.32^{0} (S76) - Transition to High Cristobalite 200-275 (∼ 220) (S76) - R.I. ω 1.487, ε 1.484 (I8) - X-ray Lines 4.02, 2.47, 2.83 (C30)

Silicon oxide - SiO_2 (High Cristobalite) - 60.06 - Colorless - Cubic - M.P. 1713 (1728 on new Int. Temp. Scale) (S76) - B.P. 2950 (R67) - R.I. 1.466 (G66) - X-ray Lines 4.14, 2.53, 1.64 (A41)

Silicon oxide - SiO_2 (Nat. Chalcedony) - 60.06 - Fibrous - D 2.55-2.63 (W43) - R.I. ω 1.537, ε 1.530 (W43)

Silicon oxide - SiO_2 (Nat. Lechatelierite) - 60.06 - Vitreous - D 2.19 (W43) - R.I. 1.458 (W43)

Silicon oxide - SiO_2 (Super Low Quartz) - 60.06 - Colorless - Transition to Low Quartz > -182.4 (O13)

Silicon oxide - SiO_2 (Low Quartz) - 60.06 - Colorless - Hexagonal - D 2.6485^{28} (R59) - Transition to High Quartz 573 (S76) - R.I. ω 1.544, ε 1.553 (S76) - X-ray Lines 3.34, 1.809, 1.533 (C30)

Silicon oxide - SiO_2 (High Quartz) - 60.06 - Colorless - Hexagonal - Metastable M.P. 1430 (S76) - Transition to Tridymite 867 (K77) - R.I. ω 1.533, ε 1.540 (580° C) (R28)

Silicon oxide - SiO_2 (Low Tridymite) - 60.06 - Colorless - Rhombic - D 2.26^{0} (S76) - Transition to Lower High-Tridymite 117 (S76) - R.I. α 1.478, β 1.479, γ 1.481 (D42) - X-ray Lines 4.29, 4.07, 3.80 (C30)

Silicon oxide - SiO_2 (Lower High-Tridymite) - 60.06 - Colorless - Hexagonal - Transition to Upper High-Tridymite 163 (S76) -

Silicon oxide - SiO_2 (Upper High-Tridymite) - 60.06 - Colorless - Hexagonal - Metastable M.P. 1670 (S76) - Transition to High Cristobalite 1470 (S76)

Silicon oxide - SiO_2 (Glass) - 60.06 - Colorless - D 2.203^{0} (S76) - R.I. 1.4585 (M77)

Silicon phosphate - $SiO_2 \cdot P_2O_5$ - 202.02 - Colorless - Cubic - D 3.23 (X-ray) (L44)

Silicon sulfide, mono- - SiS - 60.13 - Yellow and Black - Needle-Like - D 1.853^{18} (M29)

Silicon sulfide - SiS_2 - 92.19 - Colorless - Rhombic - D 2.02 (T34) - M.P. 1090 (T34)

SILICON, ORGANO-COMPOUNDS OF

SiH_4 - 32.09 - D 0.68^{-185} (R39) - M.P. -184.7 (S99) - B.P. -112 (R39)

SiD_4 - 36.11 - M.P. -186.5 (S99)

Si_2H_6 - 62.17 - D 0.686^{-25} (R39) - M.P. -129.3 (S99) - B.P. -14.5 (R39)

Si_2D_6 - 68.20 - M.P. -130.2 (S99)

Si_3H_8 - 92.24 - D 0.743^{0} (R39) - M.P. -116.9 (S99) - B.P. 52.9 (R39)

Si_3D_8 - 100.29 - M.P. -116.8 (S99)

Si_4H_{10} - 122.32 - D 0.825^{0} (R39) - M.P. -91.5 (S99) - B.P. ca. 109 (R39)

Si_4D_{10} - 132.38 - M.P. -89.5 (S99)

CH_3SiH_3 - 46.12 - D 0.62^{-57} (R39) - M.P. -157 (R39) - B.P. -57 (R39)

$C_2H_5SiH_3$ - 60.14 - B.P. -14 (F17)

$n\text{-}C_3H_7SiH_3$ - 74.17 - D 0.6434^{20} (F17) - B.P. 23 (F17) - R.I. 1.3759^{20} (F17)

$n\text{-}C_4H_9SiH_3$ - 88.20 - D $.6764^{20}$ (F17) - B.P. 55 (F17) - R.I. 1.3929^{20} (F17)

$C_6H_5SiH_3$ - 108.18 - D 0.8681^{20} (F17) - B.P. 120 (F17) - R.I. 1.5125^{20} (F17)

$(CH_3)_2SiH_2$ - 60.14 - D 0.68^{-80} (R39) - M.P. -150 (R39) - B.P. -20 (R39)

$(C_2H_5)_2SiH_2$ - 88.20 - D 0.6832^{20} (F17) - B.P. 54 (F17) - R.I. 1.3918^{20} (F17)

$(n\text{-}C_3H_7)_2SiH_2$ - 116.25 - D $.7194^{20}$ (F17) - B.P. 111 (F17) - R.I. 1.4112^{20} (F17)

$(CH_3)_3SiH$ - 74.17 - B.P. 10 (T10)

$(C_2H_5)_3SiH$ - 116.25 - D 0.751^{0} (R39) - B.P. 107 (R39)

$(n\text{-}C_3H_7)_3SiH$ - 158.33 - D 0.772^{0} (R39) - B.P. 170 (R39)

$(i\text{-}C_4H_9)_3SiH$ - 200.40 - B.P. 204 (R39)

$(i\text{-}C_5H_{11})_3SiH$ - 242.48 - B.P. 245 (R39)

$(C_6H_5)_3SiH$ - 260.37 - M.P. 36 (R39)

$(C_6H_5CH_2)_3SiH$ - 302.45 - M.P. 91 (R39)

$(CH_3)_4Si$ - 88.20 - Colorless - D 0.646^{20} (R39) - B.P. 26 (R39) - R.I. 1.35912° (K90)
$(C_2H_5)_4Si$ - 144.30 - D 0.766^{20} (R39) - B.P. 154 (R39) - R.I. 1.42463° (K90)
$(n\text{-}C_3H_7)_4Si$ - 200.40 - D 0.785^{20} (R39) - B.P. 213 (R39)
$(n\text{-}C_4H_9)_4Si$ - 256.51 - D 0.822^{20} (R39) - B.P. 231 (R39)
$(i\text{-}C_5H_{11})_4Si$ - 312.61 - B.P. 275 (R39)
$(C_6H_5)_4Si$ - 336.46 - Tetragonal - D 1.078^{20} (R39) - M.P. 233 (R39) - B.P. 530 (R39)
$(m\text{-}CH_3\cdot C_6H_4)_4Si$ - 392.56 - D 1.118^{20} (R39) - M.P. 151 (R39)
$(p\text{-}CH_3\cdot C_6H_4)_4Si$ - 392.56 - D 1.079^{20} (R39) - M.P. 228 (R39)
$(C_6H_5CH_2)_4Si$ - 392.56 - D 1.078^{20} (R39) - M.P. 128 (R39) - B.P.:> 550 (R39)
$(C_6H_5\cdot C_6H_4)_4Si$ - 640.82 - M.P. 274 (R39)
$(CH_3)_3(C_2H_5)Si$ - 102.22 - D 0.6839^{20} (K90) - B.P. 63 (K90) - R.I. 1.3828° (K90)
$(CH_3)_3(n\text{-}C_3H_7)Si$ - 116.25 - D 0.7017^{20} (K90) - B.P. 90 (K90) - R.I. 1.39079° (K90)
$(CH_3)_3(n\text{-}C_4H_9)Si$ - 130.27 - D 0.7182^{20} (K90) - B.P. 115 (K90) - R.I. 1.40035° (K90)
$(CH_3)_3(i\text{-}C_4H_9)Si$ - 130.27 - D 0.7161^{20} (K90) - B.P. 108 (K90) - R.I. 1.39883° (K90)
$(CH_3)_3(i\text{-}C_5H_{11})Si$ - 144.30 - D 0.7281 (K90) - B.P. 132 (K90) - R.I. 1.40571° (K90)
$(CH_3)_3C_6H_5Si$ - 150.26 - D 0.8691^{20} (K90) - B.P. 172 (R39) - R.I. 1.48830 (K90)
$(CH_3)_3(C_7H_7)Si$ - 164.29 - D 0.8679^{20} (K90) - B.P. 191 (K90) - R.I. 1.49094° (K90)
$(C_2H_5)_3(n\text{-}C_3H_7)Si$ - 158.33 - D 0.7721^{20} (K90) - B.P. 172 (K90) - R.I. 1.42886° (K90)
$(C_2H_5)_3(n\text{-}C_4H_9)Si$ - 172.35 - D 0.7782 (K90) - B.P. 191 (K90) - R.I. 1.43223° (K90)
$(C_2H_5)_3(i\text{-}C_4H_9)Si$ - 172.35 - D 0.7798^{20} (K90) - B.P. 187 (K90) - R.I. 1.43333° (K90)
$(C_2H_5)_3(i\text{-}C_5H_{11})Si$ - 186.38 - D 0.7808 (K90) - B.P. 204 (K90) - R.I. 1.43361° (K90)
$(C_2H_5)_3C_6H_5Si$ - 192.34 - D 0.906° (R39) - B.P. 238 (R39) - R.I. 1.50035° (K90)
$(CH_3)_2(C_2H_5)_2Si$ - 116.25 - D 0.7171 (K90) - B.P. 96 (K90) - R.I. 1.39819° (K90)
$(CH_3)_2(n\text{-}C_3H_7)_2Si$ - 144.30 - D 0.7396 (K90) - B.P. 141 (K90) - R.I. 1.41193° (K90)
$(CH_3)_2(\text{-}CH_2\text{-})_5Si$ - 128.26 - D 0.8039^{20} (K90) - B.P. 133 (K90) - R.I. 1.43940° (K90)
$(CH_3)_2(C_6H_5)_2Si$ - 212.33 - B.P. 176 (45m.m.) (R39)
$(C_2H_5)_2(C_6H_5)_2Si$ - 240.38 - B.P. 305 (R39)
$(CH_3)_2(C_2H_5)(i\text{-}C_4H_9)Si$ - 144.30 - D 0.7422^{20} (K90) - B.P. 138 (K90) - R.I. 1.41296° (K90)
$(CH_3)_2(C_2H_5)(n\text{-}C_3H_7)Si$ - 130.27 - D 0.7302 (K90) - B.P. 121 (K90) - R.I. 1.40624° (K90)
$(CH_3)_2(C_2H_5)(C_6H_5)Si$ - 164.29 - D 0.8771^{20} (K90) - B.P. 198 (K90) - R.I. 1.49281 (K90)

$CH_3(C_6H_5)_3Si$ - 274.39 - M.P. 67 (39)
$C_2H_5(C_6H_5)_3Si$ - 288.42 - M.P. 76 (R39)
$(CH_3)(C_2H_5)(n\text{-}C_3H_7)(C_6H_5)Si$ - 192.34 - B.P. 228 (R39)
$(C_2H_5)(n\text{-}C_3H_7)(i\text{-}C_4H_9)(CH_2C_6H_5)Si$ - 248.44 - B.P. 282 (R39)
$(CH_3)_6Si_2$ - 146.32 - D 0.723^{20} (R39) - M.P. 12 (R39) - B.P. 113 (K90) - R.I. 1.42074 (K90)
$(C_2H_5)_6Si_2$ - 230.48 - D 0.8403^{20} (R39) - B.P. 255 (R39)
$(C_3H_7)_6Si_2$ - 314.64 - D 0.869^{20} (R39) - B.P. 114 (3 m.m.) (R39)
$(C_6H_5)_6Si_2$ - 518.72 - M.P. 335 (R39)
$(p\text{-}CH_3C_6H_4)_6Si_2$ - 602.88 - M.P. 345 (R39)
$(C_6H_5CH_2)_6Si_2$ - 602.88 - M.P. 194 (R39)
$(C_2H_5)_2(C_3H_7)_2(C_6H_5)_2Si_2$ - 354.61 - B.P. 270 (100 m.m.) (R39)
$(C_2H_5)_2(C_3H_7)_2(C_6H_5CH_2)_2Si_2$ - 382.66 - B.P. 244 (20 m.m.) (R39)
$(C_2H_5)_3Si(C_6H_4)Si(C_2H_5)_3$ - 307.58 - Colorless - D 0.8967^{20} (K90) - B.P. 195 (16.5 m.m.) (K90) - R.I. $1.5094^{15.7}$ (K90)
-$(C_6H_5)_8Si_4$- - 729.04 - M.P. 335 (R39)
$[(C_6H_5)_2Si]_4$ - 729.04 - M.P. 400 (R39)
$[(p\text{-}CH_3C_6H_4)_2Si]_4$ - 841.25 - M.P. 310
-$(p\text{-}CH_3 \cdot C_6H_4)_8Si_4$- - 841.25 - M.P. 293 (R39)
$(C_2H_5)_2(C_6H_5)_8Si_4$ - 787.16 - M.P. 254 (R39)

Silicon - Halogenated Organic Compounds:

SiF_4 - 104.06 - Colorless Gas - D 1.66^{-95} (Liquid), 2.133^{-183} (Solid) (L36) - M.P. -90.2 (1318 m.m.) (P19) - S.P. -95.7 (1 atm.) (K39) - X-ray Lines 2.21, 1.28, 3.83
Si_2F_6 - 170.12 - Colorless - M.P. -18.5 (K15) - S.P. -19.1 (S33)
$SiHF_3$ - 86.07 - M.P. -131 (R39) - B.P. -97.5 (R39)
SiH_2F_2 - 68.08 - M.P. -119 (R39) - B.P. -77.5 (R39)
$(C_2H_5)_3SiF$ - 134.24 - D 0.835^{25} (R39) - B.P. 109 (R39)
$(n\text{-}C_3H_7)_3SiF$ - 176.32 - D 0.834^{25} (R39) - B.P. 175 (R39)
$(n\text{-}C_4H_9)_3SiF$ - 218.40 - D 0.837^{25} (R39) - B.P. 224 (R39)
$(n\text{-}C_5H_{11})_3SiF$ - 260.47 - D 0.839^{25} (R39) - B.P. 267 (R39)
$(C_6H_5)_3SiF$ - 278.36 - M.P. 64 (R39) - B.P. 200 (10 m.m.) (R39)
$(C_6H_5CH_2)_3SiF$ - 320.44 - M.P. 79 (R39) - B.P. 236 (7.5 m.m.) (R39)
$SiCl_4$ - 169.89 - Colorless Liquid - D 1.469^{25} (A27) - M.P. -70 (A27) - B.P. 57.57 (A27) - R.I. 1.4126 (A27)
Si_2Cl_6 - 268.86 - Colorless Liquid - D 1.58^{0} (Liquid) (R12) - M.P. 2 (K90) - B.P. 147 (K90)
Si_3Cl_8 - 367.84 - B.P. 216 (R39)
Si_4Cl_{10} - 466.81 - B.P. 150 (15 m.m.) (R39)
$SiCl_3Br$ - 214.35 - D 1.826^{25} (A28) - M.P. -62 (A28) - B.P. 80.3 (A28)
$SiCl_2Br_2$ - 258.81 - D 2.172^{25} (A28) - M.P. - 45.5 (A28) - B.P. 104.4 (A28)
$SiClBr_3$ - 303.26 - D 2.497^{25} (A28) - M.P. -20.8 (A28) - B.P. 128.0 (A28)
$Cl_3SiOSiCl_3$ - 284.9 - White - D 1.550 (D32) - B.P. 137 (D32)
$SiHCl_3$ - 135.44 - D 1.35^{0} (R39) - M.P. -127 (R39) - B.P. 31.8 (T10)
CH_3SiCl_3 - 149.46 - Colorless - D 1.271^{20} (R39) - B.P. 66 (R39) - R.I. 1.4085 (D32)

$C_2H_5SiCl_3$ - 163.49 - Colorless - D 1.238^{20} (R39) - B.P. 100 (R39) - R.I. 1.42573 (K90)
$CH_2{=}CH{-}SiCl_3$ - 161.48 - D 1.264^{27} (R39) - B.P. 92 (R39)
n-$C_3H_7SiCl_3$ - 177.52 - D 1.196^{20} (R39) - B.P. 125 (39) - R.I. 1.43121° (K90)
$CH_2{=}CHCH_2SiCl_3$ - 175.50 - D 1.211^{27} (R39) - B.P. 117 (R39)
n-$C_4H_9SiCl_3$ - 191.54 - D 1.161^{20} (R39) - B.P. 149 (R39) - R.I. 1.43630° (K90)
i-$C_4H_9SiCl_3$ - 191.54 - D 1.161^{16} (R39) - B.P. 140 (R39)
i-$C_5H_{11}SiCl_3$ - 205.57 - D 1.07^{20} (R39) - B.P. 56 (17 m.m.) (R39)
$C_6H_{11}SiCl_3$ - 217.58 - B.P. 208 (R39)
$C_{12}H_{25}SiCl_3$ - 303.7 - Colorless - D 1.026 (D32) - B.P. 288 (D32) - R.I. 1.4521 (D32)
$C_{16}H_{33}SiCl_3$ - 359.9 - Colorless - D 0.996 (D32) - B.P. 269 (100 m.m.) (D32)- R.I. 1.457 (D32)
$C_{18}H_{37}SiCl_3$ - 387.9 - Colorless - D 0.984 (D32) - B.P. 291 (100 m.m.) (D32) - R.I. 1.458 (D32)
$C_6H_5SiCl_3$ - 211.53 - Colorless - D 1.28^{20} (R39) - B.P. 199 (R39) - R.I. 1.52434 (K90)
p-$CH_3{\cdot}C_6H_4{\cdot}SiCl_3$ - 225.56 - B.P. 219 (R39)
$C_6H_5CH_2SiCl_3$ - 225.56 - D 1.283^{20} (R39) - B.P. 216 (R39) - R.I. 1.52572° (K90)
α-$C_{10}H_7SiCl_3$ - 261.59 - D 1.376^{20} (R39) - B.P. 168 (22 m.m.) (R39)
SiH_2Cl_2 - 100.99 - D 1.42^{-122} (R39) - M.P. -122 (R39) - B.P. 8.3 (R39)
$(CH_3)_2SiCl_2$ - 129.042 - Colorless - D 1.062^{20} (R39) - M.P. -86 (R39) - B.P. 70 (R39) - R.I. 1.402 (D32)
$(C_2H_5)_2SiCl_2$ - 157.09 - Colorless - D 1.053 (D32) - B.P. 129 (R39) - R.I. 1.431 (D32)
(n-$C_3H_7)_2SiCl_2$ - 185.15 - Colorless - B.P. ∼ 176 (R39)
$(CH_2{=}CH)(CH_3)SiCl_2$ - 141.05 - D 1.085^{27} (R39) - B.P. 93 (R39)
$CH_2{=}CHCH_2SiHCl_2$ - 141.05 - D 1.086^{27} (R39) - B.P. 97 (R39)
$(CH_2{=}CH)_2SiCl_2$ - 153.06 - D 1.081^{27} (R39) - B.P. 118 (R39)
$(CH_2{=}CHCH_2)(CH_3)SiCl_2$ - 155.08 - D 1.057^{27} (R39) - B.P. 119 (R39)
C_2H_5(n-$C_3H_7)SiCl_2$ - 171.12 - D 1.043^{20} (R39) - B.P. 153 (R39) - R.I. 1.43587° (K90)
$(-CH_2-)_5SiCl_2$ - 169.10 - D 1.1560^{20} (K90) - B.P. 170.0 (K90) - R.I. 1.46973° (K90)
C_2H_5(i-$C_4H_9)SiCl_2$ - 185.15 - D 1.024^{20} (R39) - B.P. 169 (R39) - R.I. 1.44037° (K90)
$CH_2{=}CHCH_2)_2SiCl_2$ - 140.04 - B.P. ca. 83 (50 m.m.) (R39)
$(C_6H_5)_2SiCl_2$ - 253.17 - Light Straw - D 1.19^{20} (R39) - M.P. -22 (R39) - B.P. 303 (R39) - R.I. 1.577 (D32)
(p-$CH_3{\cdot}C_6H_4)_2SiCl_2$ - 281.23 - B.P. 238 (50 m.m.) (R39)
$(C_6H_5CH_2)_2SiCl_2$ - 281.23 - Colorless - Prism - M.P. 51 (R39) - B.P. 243 (100 m.m.) (R39)
$C_2H_5(C_6H_5)SiCl_2$ - 205.13 - Colorless - B.P. 230 (R39)
$C_2H_5(C_6H_5CH_2)SiCl_2$ - 219.16 - B.P. 169 (100 m.m.) (R39)
$C_6H_5(C_6H_5CH_2)SiCl_2$ - 267.20 - B.P. 245 (100 m.m.) (R39)
(p-$BrC_6H_4)_2SiCl_2$ - 410.99 - M.P. 60 (R39) - B.P. 239 (21 m.m.) (R39)
C_6H_5(p-$BrC_6H_4)SiCl_2$ - 332.08 - D 1.501^{20} (R39) - B.P. 200 (14 m.m.) (R39)

$Cl[(CH_3)_2SiO]_1Si(CH_3)_2Cl$ - 203.17 - D 1.038^{20} (R39) - M.P. -37 (R39) - B.P. 138 (R39)
$Cl[(CH_3)_2SiO]_2Si(CH_3)_2Cl$ - 277.30 - D 1.018^{20} (R39) - M.P. -53 (R39) - B.P. 184 (R39)
$Cl[(CH_3)_2SiO]_3Si(CH_3)_2Cl$ - 351.43 - D 1.011^{20} (R39) - M.P. -62 (R39) - B.P. 222 (R39)
$Cl[(CH_3)_2SiO]_4Si(CH_3)_2Cl$ - 425.55 - D 1.005^{20} (R39) - M.P. ca.-80 (R39) - B.P. 138 (20 m.m.) (R39)
$Cl[(CH_3)_2SiO]_5Si(CH_3)_2Cl$ - 499.68 - D 1.003^{20} (R39) - M.P. ca.-80 (R39) - B.P. 161 (20 m.m.) (R39)
SiH_3Cl - 66.54 - D 1.15^{-113} (R39) - M.P. -118 (R39) - B.P. -30.4 (R39)
$(CH_3)_3SiCl$ - 108.62 - Colorless - D 0.846^{20} (T10) - M.P. -40 (T10) - B.P. 57.6 (R39) - R.I. 1.389 (D32)
$(C_2H_5)_3SiCl$ - 150.70 - D 0.925^{0} (R39) - B.P. 143.5 (R39)
$(CH_2=CHCH_2)(CH_3)_2SiCl$ - 132.68 - D 0.922^{27} (R39) - B.P. ca. 112 (R39)
$C_2H_5(C_6H_5)_2SiCl$ - 246.78 - B.P. 208 (50 m.m.) (R39)
$(C_6H_5)(C_2H_5)(n\text{-}C_3H_7)SiCl$ - 212.76 - B.P. ca. 250 (R39)
$(C_6H_5CH_2)(C_2H_5)(n\text{-}C_3H_7)SiCl$ - 226.79 - B.P. 174 (50 m.m.) (R39)
$(C_6H_5CH_2)(C_2H_5)(i\text{-}C_4H_9)SiCl$ - 240.82 - B.P. 200 (100 m.m.) (R39)
$(C_6H_5)_3SiCl$ - 294.82 - White - M.P. 111 (R39) - M.P. 365 (R39)
$(p\text{-}CH_3\cdot C_6H_4)_3SiCl$ - 336.90 - M.P. 116 (R39)
$(C_6H_5CH_2)_3SiCl$ - 336.90 - Prism - M.P. 141 (R39) - B.P. 300-360° (100 m.m.) (R39)
$SiBr_4$ - 347.72 - Colorless Liquid - D 2.812^{25} (A28) - M.P. 5 (A28) - B.P. 153 (R12)
$SiHBr_3$ - 268.82 - M.P. -73.5 (R39) - B.P. 111.8 (R39)
CH_3SiBr_3 - 282.84 - B.P. 133.5 (R39)
SiH_2Br_2 - 189.91 - D 2.17^{0} (R39) - M.P. -70.1 (R39) - B.P. ca. 66 (R39)
$(CH_3)_2SiBr_2$ - 217.96 - B.P. 112.3 (R39)
$(C_6H_5)_2SiBr_2$ - 342.09 - B.P. 180 (12 m.m.) (R39)
SiH_3Br - 111.00 - D 1.53^{0} (R39) - M.P. -94 (R39) - B.P. 1.9 (R39)
$(CH_3)_3SiBr$ - 153.08 - D 1.148^{25} (R39) - B.P. 80.0 (R39)
$(C_2H_5)_3SiBr$ - 195.16 - D 1.177^{20} (R39) - B.P. 161 (R39) - R.I. 1.4670^{187} (K90)
$(n\text{-}C_3H_7)_3SiBr$ - 237.23 - B.P. 213 (R39)
$(i\text{-}C_4H_9)_3SiBr$ - 279.31 - B.P. 245 (R39)
$(i\text{-}C_5H_{11})_3SiBr$ - 321.39 - B.P. 278 (R39)
$(C_6H_5)_3SiBr$ - 339.28 - Colorless - Needle - M.P. 120 (R)
SiI_4 - 535.74 - Colorless - Cubic - M.P. 120.5 (S41) - B.P. 287.5° (S41)
Si_2I_6 - 817.64 - Colorless - Hexagonal - D 0.8403^{20} (K90) - M.P. 250 (R12) - D.T. 250 (S41)
$SiHI_3$ - 409.83 - D 3.31^{20} (R39) - M.P. 8 (R39) - B.P. 220 (R39)
SiH_3I - 158.00 - M.P. -56.5 (R39) - B.P. 45.8 (R39)

Silicon - Organic Alcohols:

$(CH_3)_3SiOH$ - 90.17 - B.P. 97 (R39)
$(C_2H_5)_3SiOH$ - 132.25 - D 0.865^{20} (R39) - B.P. 154 (R39) - R.I. $1.4364^{16.5}$ (K90)

$(C_2H_5)_3SiOH$ - 132.25 - D 0.865^{20° (R39) - B.P. 154 (R39) - R.I. $1.4364^{16.5}$ (K90)
$(n\text{-}C_3H_7)_3SiOH$ - 174.33 - B.P. 207 (R39)
$(i\text{-}C_5H_{11})_3SiOH$ - 258.48 - B.P. 270 (R39)
$(C_6H_5)_3SiOH$ - 276.37 - White - M.P. 151 (R39)
$(p\text{-}CH_3C_6H_4)_3SiOH$ - 318.45 - M.P. 100 (R39)
$(C_6H_5CH_2)_3SiOH$ - 318.45 - M.P. 106 (R39)
$(CH_3)(C_2H_5)(C_6H_5)SiOH$ - 166.26 - B.P. 115 (17 m.m.) (R39)
$(C_2H_5)_2(C_6H_5CH_2)SiOH$ - 194.31 - B.P. 165 (40 m.m.) (R39)
$(C_2H_5)_2(C_6H_5)SiOH$ - 180.29 - B.P. 165 (60 m.m.) (R39)
$CH_3(C_6H_5CH_2)_2SiOH$ - 242.35 - B.P. 241 (60 m.m.) (R39)
$(C_2H_5)(n\text{-}C_3H_7)(C_6H_5)SiOH$ - 194.31 - Colorless - B.P. $\sim$ 250 (R39)
$C_2H_5(C_6H_5CH_2)_2SiOH$ - 256.38 - B.P. 210 (25 m.m.) (R39)
$(C_2H_5)(n\text{-}C_3H_7)(C_6H_5CH_2)SiOH$ - 208.34 - B.P. 155 (25 m.m.) (R39)
$(C_2H_5)(i\text{-}C_4H_9)(C_6H_5CH_2)SiOH$ - 222.37 - B.P. 163 (25 m.m.) (R39)
$C_2H_5(C_6H_5)Si(OH)_2$ - 168.24 - M.P. 70 (R39)
$C_2H_5(C_6H_5CH_2)Si(OH)_2$ - 182.26 - M.P. 99 (R39)
$(C_6H_5)_2Si(OH)_2$ - 216.28 - White - M.P. 132 (R39)
$(C_6H_5CH_2)_2Si(CH)_2$ - 244.33 - M.P. 101 (R39)
$(C_6H_5)_4Si_2O(OH)_2$ - 414.54 - M.P. 113 (R39)
$(C_2H_5)_2(C_6H_5)_2Si_2O(OH)_2$ - 318.46 - M.P. 87.5 (R39)
$(C_6H_5CH_2)_4Si_2O(OH)_2$ - 470.64 - M.P. 76 (R39)
$(C_6H_5)_6Si_3O_2(OH)_2$ - 612.80 - M.P. 111 (R39)
$(C_6H_5CH_2)_6Si_3O_2(OH)_2$ - 696.95 - M.P. 82 (R39)

Silicon - Organic Ethers, Esters, Acetals, etc.:

$(SiH_3)_2O$ - 78.168 - D 0.881^{-80° (R39) - M.P. -144 (R39) - B.P. -15.2 (R39)
$(CH_3)_6Si_2O$ - 162.32 - White - D 0.7619^{20° (R39) - B.P. 100 (R39) - R.I. 1.375 (D32)
$(C_2H_5)_6Si_2O$ - 246.48 - D 0.859^{0° (R39) - B.P. 231 (R39)
$(C_3H_7)_6Si_2O$ - 330.64 - B.P. ca. 285 (R39)
$(C_5H_{11})_6Si_2O$ - 498.95 - B.P. ca. 365 (R39)
$(C_6H_5)_6Si_2O$ - 534.72 - M.P. 221 (R39)
$(p\text{-}CH_3C_6H_4)_6Si_2O$ - 618.88 - M.P. 224 (R39)
$(CH_3)_2(C_6H_5)_4Si_2O$ - 410.59 - M.P. 52 (R39)
$(C_2H_5)_2(C_6H_5)_4Si_2O$ - 438.64 - M.P. 66 (R39)
$(C_2H_5)_2(n\text{-}C_3H_7)_2(C_7H_7)_2Si_2O$ - 398.66 - B.P. 272 (50 m.m.) (R39)
$(C_2H_5)_2(i\text{-}C_4H_9)_2(C_6H_5CH_2)_2Si_2O$ - 426.72 - B.P. 252 (20 m.m.) (R39)
$(C_6H_5)_8Si_4O$ - 745.04 - M.P. ca. 240 (R39)
$(C_6H_5)_8Si_4O_2$ - 761.04 - M.P. 222 (R39)
$(p\text{-}CH_3C_6H_4)_8Si_4O$ - 857.25 - M.P. 229 (R39)
$(CH_3O)_6Si_2O$ - 258.32 - B.P. 201 (R39)
$(C_2H_5O)_6Si_2O$ - 342.48 - B.P. 235 (R39)
$(CH_3)_3SiOCH_3$ - 104.20 - B.P. 57 (R39)
$(CH_3)_3SiOC_2H_5$ - 118.22 - D 0.758^{20° (R39) - B.P. 75 (R39) - R.I. 1.374 (D32)
$(CH_3)_3SiOC_4H_9$ - 146.27 - D 0.777^{20° (R39) - B.P. 123 (R39)
$(CH_3)_2Si(OC_2H_5)_2$ - 148.25 - Colorless - D 0.890^{20° (R39) - B.P. 111 (R39) - R.I. 1.378 (D32)

$(CH_3)_2Si(OC_4H_9)_2$ - 204.35 - D 0.843^{20} (R39) - B.P. 187 (R39)
$(C_2H_5)_2Si(OC_2H_5)_2$ - 176.30 - D 0.875^{0} (R39) - B.P. 156 (R39)
$(C_6H_5C \equiv C)_2Si(OC_2H_5)_2$ -320.42 - B.P. 185 (12 m.m.) (R39)
$(C_6H_5O)_2(C_6H_5)_8Si_4$ - 819.16 - M.P. 216 (R39)
$CH_3Si(OC_2H_5)_3$ - 178.27 - Colorless - D 0.885 (D32) - B.P. 143.5 (D32) - R.I. 1.382 (D32)
$CH_3Si(OC_4H_9)_3$ - 262.43 - D 0.877^{20} (R39) - B.P. 115 (10 m.m.) (R39)
$C_2H_5Si(OCH_3)_3$ - 150.22 - D 0.975^{0} (R39) - B.P. 126 (R39)
$C_3H_5Si(OC_2H_5)_3$ - 204.31 - D 0.923^{20} (R39) - B.P. 175 (R39)
$C_2H_5Si(OC_2H_5)_3$ - 192.30 - D 0.921^{0} (R39) - B.P. 159 (R39)
i-$C_3H_2Si(OC_2H_5)_3$ - 206.33 - D 0.919^{20} (R39) - B.P. 178 (R39)
i-$C_4H_9Si(OC_2H_5)_3$ - 220.35 - D 0.910^{20} (R39) - B.P. 186 (R39)
i-$C_5H_{11}Si(OC_2H_5)_3$ - 234.38 - D 0.896^{20} (R39) - B.P. 198 (R39)
$C_6H_{13}Si(OC_2H_5)_3$ - 248.40 - D 0.894^{20} (R39) - B.P. 210 (R39)
$C_6H_5Si(OC_2H_5)_3$ - 240.34 - D 1.013^{0} (R39) - B.P. 234 (R39)
$C_6H_5CH_2Si(OC_2H_5)_3$ - 254.37 - D 0.986^{20} (R39) - B.P. 253 (R39)
$C_6H_5C \equiv C{-}Si(OC_2H_5)_3$ - 264.36 - B.P. 141 (6 m.m.) (R39)
$C_6H_5Si(OC_6H_5)_3$ - 384.46 - B.P. 250 (13 m.m.) (R39)
$Si(OCH_3)_4$ - 152.20 - D 1.0234^{20} (F38) - B.P. 121.0 (F38) - R.I. 1.3683 (F38)
$Si(OC_2H_5)_4$ - 208.30 - D 0.933^{20} (R39) - B.P. 168.1 (D32) - R.I. 1.383 (D32)
$Si(OC_4H_9)_4$ - 320.51 - D 0.953^{25} (R39) - B.P. 163 (20 m.m.) (R39)
$Si(OC_5H_{11})_4$ - 376.61 - D 0.893^{25} (R39) - B.P. 148 (3 m.m.) (R39)
$Si(OC_6H_5)_4$ - 400.46 - M.P. 48 (R39)
$Si(OCH_2C_6H_5)_4$ - 456.56 - D 1.118 (D32) - M.P. 32.5 (R39) - B.P. 425 (D32) - R.I. 1.557 (D32)
$(SiCl_3)_2O$ - 284.86 - M.P. -33 (R39) - B.P. 137 (R39)
$(SiBr_3)_2O$ - 551.62 - M.P. 27.9 (R39) - B.P. 118 (15 m.m.) (R39)

Silicon - Organo Polymers:

$[(CH_3)_2SiO]_3$ - 222.38 - M.P. 64 (R39) - B.P. 134 (R39)
$[(CH_3)_2SiO]_4$ - 296.51 - D 0.9558^{20} (R39) - M.P. 17.5 (R39) - B.P. 175 (R39)
$[(CH_3)_2SiO]_5$ - 370.64 - D 0.9593^{20} (R39) - M.P. -38 (R39) - B.P. 210 (R39)
$[(CH_3)_2SiO]_6$ - 444.77 - D 0.9672 (R39) - M.P. -3 (R39) - B.P. 245 (R39)
$[(CH_3)_2SiO]_7$ - 518.90 - D 0.9730^{20} (R39) - M.P. -26 (R39) - B.P. 154 (20 m.m.) (R39)
$[(CH_3)_2SiO]_8$ - 593.02 - M.P. ca. 30 (R39) - B.P. 175 (20 m.m.) (R39)
$[(CH_3)_2SiO]_9$ - 667.15 - B.P. ca. 188 (20 m.m.) (R39)
$[(C_2H_5)_2SiO]_3$ - 306.54 - B.P. 144 (17 m.m.) (R39)
$(C_6H_5)_6Si_3O_3$ - 594.78 - M.P. 190 (R39) - B.P. 295 (1 m.m.) (R39)
$(C_6H_5)_8Si_4O_4$ - 793.04 - M.P. 202 (R39) - B.P. 335 (1 m.m.) (R39)
$(C_6H_5CH_2)_6Si_3O_3$ - 678.94 - M.P. 98 (R39)
$(C_2H_5 \cdot C_6H_5SiO)_3$ - 492.74 - B.P. 310 (22 m.m.) (R39)
$CH_3[(CH_3)_2SiO]_2Si(CH_3)_3$ - 236.45 - D 0.8200^{20} (R39) - M.P. ca. -80 (R39) - B.P. 153 (R39)
$CH_3[(CH_3)_2SiO]_3Si(CH_3)_3$ - 310.58 - D 0.8536^{20} (R39) - M.P. ca. -70 (R39)-B.P. 194 (R39)

$CH_3[(CH_3)_2SiO]_4Si(CH_3)_3$ - 384.71 - D 0.8755^{20} (R39) - M.P. ca. -80 (R39) - B.P. 229 (710 m.m.) (R39)

$CH_3[(CH_3)_2SiO]_5Si(CH_3)_3$ - 458.84 - D 0.8910^{20} (R39) - M.P. <-100 (R39) - B.P. 142 (20 m.m.) (R39)

$CH_3[(CH_3)_2SiO]_6Si(CH_3)_3$ - 532.96 - D 0.911^{20} (R39) - B.P. 165 (20 m.m.) (R39)

$CH_3[(CH_3)_2SiO]_7Si(CH_3)_3$ - 607.09 - D 0.913^{20} (R39) - B.P. 153 (5.1 m.m.) (R39)

$CH_3[(CH_3)_2SiO]_8Si(CH_3)_3$ - 681.22 - D 0.918^{20} (R39) - B.P. 173 (4.9 m.m.) (R39)

$CH_3[(CH_3)_2SiO]_9Si(CH_3)_3$ - 755.35 - D 0.925^{20} (R39) - B.P. 183 (4.1 m.m.) (R39)

$CH_3[(CH_3)_2SiO]_{10}Si(CH_3)_3$ - 829.48 - D 0.930^{20} (R39) - B.P. 201 (4.7 m.m.) (R39)

Silicon - Misc. Organic Compounds:

$(SiH_3)_3N$ - 76.18 - D 0.895^{-106} (R39) - M.P. -106 (R39) - B.P. 52 (R39)

$(CH_3)_6Si_2NH$ - 161.34 - D 0.7742^{20} (R39) - B.P. 125 (R39)

$SiCl_3(CNO)$ - 176.45 - D 1.445^{28} (A27) - M.P. -69 (A27) - B.P. 86.8 (A27) - R.I. 1.4262 (A27)

$SiCl_2(CNO)_2$ - 183.01 - D 1.437^{28} (A27) - M.P. -80 (A27) - B.P. 117.8 (A27) - R.I. 1.4380 (A27)

$SiCl(CNO)_3$ - 189.57 - D 1.437^{28} (A27) - M.P. -35 (A27) - B.P. 152.0 (A27) - R.I. 1.4507 (A27)

$Si(SC_6H_5)_4$ - 464.724 - Rhombic - M.P. 114.7 (W43) - R.I. α 1.698, β 1.750, γ 1.757 (W43)

$Si(OCN)_4$ - 196.13 - Colorless - D 1.414^{20} (F37) - M.P. 34.5 (F37) - B.P. 247.2 (F37) - R.I. 1.4646 (F37)

$Si(NCO)_4$ - 196.13 - Colorless - D 1.434^{28} (A27) - M.P. 26.0 (A27) - B.P. 185.6 (A27) - R.I. 1.4610 (A27)

$Si(OCH_3)_3NCO$ - 163.18 - D 1.123^{20} (F38) - B.P. 137.6 (F38) - R.I. 1.3839^{20} (F38)

$Si(OCH_3)_2(NCO)_2$ - 174.16 - D 1.208^{20} (F38) - B.P. 152 (F38) - R.I. 1.4028^{20} (F38)

$Si(OCH_3)(NCO)_3$ - 185.15 - D 1.313^{20} (F38) - B.P. 168.4 (F38) - R.I. 1.4287^{20} (F38)

$Si(NCO)_4$ - 196.13 - D 1.442^{20} (F38) - B.P. 185.6 (F38) - R.I. 1.4610^{20} (F38)

$Si(SCN)_4$ - 260.40 - Colorless - M.P. 145 (P53) - B.P. 314.2 (I8)

Silver - Ag - 107.880 - White - Cubic - D 10.49^{20} (A20) - M.P. 960.5 (A20) (I8a) - B.P. 2210 (A20) - X-ray Lines 2.37, 1.230, 2.05 (A40)

Silver aluminum silicate, hydrate - $Ag_2O \cdot Al_2O_3 \cdot 4SiO_2 \cdot 2H_2O$ (Nat. Analcime) - 609.97 - X-ray Lines 3.42, 2.91, 2.50 (A41)

Silver antimonate - $Ag_2O \cdot Sb_2O_5$ - 555.28 - X-ray Lines 2.96, 2.56, 1.81 (A41)

Silver antimony (III) sulfide - $Ag_2S \cdot Sb_2S_3$ (Nat. Miargyrite) - 587.54 - Red - Monoclinic - D 5.36 (I8) - M.P. 509 (J4) - R.I. α -, β > 2.72 (Li-Line), γ - (L18) - X-ray Lines 2.88, 3.42, 2.74 (A41)

Silver antimony (III) sulfide - $3Ag_2S \cdot Sb_2S_3$ (Nat. Pyroargyrite) - 1083.20 - Red - Trigonal - D 5.81 (T54) - M.P. 486 (J4) - R.I. ω 3.084, ε 2.881 (All for Li-Line) (I8)

Silver antimony (III) sulfide - $5Ag_2S \cdot Sb_2S_3$ (Nat. Stephanite) - 1578.85 - X-ray Lines 3.03, 2.55, 2.86 (A41)

Silver antimony (III) sulfide - $8Ag_2S \cdot Sb_2S_3$ (Polybarite) - 2322.33 - X-ray Lines 2.81, 2.47, 2.94 (A41)

Silver arsenate - $Ag_2O \cdot As_2O_5$ - 461.58 - X-ray Lines 2.74, 2.50, 1.63 (A40)

Silver arsenate - $3Ag_2O \cdot As_2O_5$ - 925.10 - Brownish Red - Cubic - D 6.657^{25} (I8) - X-ray Lines 2.74, 2.51, 1.64 (A41)

Silver arsenic (III) sulfide - $Ag_2S \cdot As_2S_3$ (Nat. Smithite) - 493.84 - Red - Monoclinic - D 4.88 (P27) - R.I. α 2.48, β 2.58, γ 2.60 (I8)

Silver arsenic (III) sulfide - $Ag_2S \cdot As_2S_3$ (Nat. Trechmannite) - 493.84 - Red - Trigonal - D 4.70 (I8) - R.I. ω 2.6 (Li-Line), ε - (I8)

Silver arsenic (III) sulfide - $3Ag_2S \cdot As_2S_3$ (Nat. Proustite) - 989.50 - Scarlet - Trigonal - D 5.49 (I8) - M.P. 490 (J4) - R.I. ω 3.088, ε 2.792 (I8) - X-ray Lines 3.20, 2.53, 2.75 (A41)

Silver arsenic (III) sulfide - $3Ag_2S \cdot As_2S_3$ (Nat. Xanthoconite) - 989.50 - Orange Yellow - Rhombic - D 5.2 (I8) - R.I. α -, β 3, γ - (I8)

Silver arsenic (III) sulfide - $8Ag_2S \cdot As_2S_3$ (Nat. Pearceite) - 2228.63 - X-ray Lines 2.84, 3.00, 3.09 (A41)

Silver arsenite - $3Ag_2O \cdot As_2O_3$ - 893.10 - Yellow - D.T. 150 (I8)

Silver carbonate - Ag_2CO_3 - 275.770 - Colorless or Yellow - D 6.077 (I8) - D.T. 219 (1 atm. CO_2) (K79) - X-ray Lines 2.65, 2.73, 2.27 (A40)

Silver chlorate - $AgClO_3$ - 191.337 - White - Tetragonal - D 4,48 (X-ray) (S119) - M.P. 230 (K79) - D.T. 270 (R12) - X-ray Lines 2.89, 1.71, 1.27 (A41)

Silver chlorate, per- - $AgClO_4$ - 207.337 - White - Cubic - D 4.07^{180} (X-ray) (F53) (S119) - M.P. 486 (K79) - X-ray Lines 3.48, 2.46, 2.10 (A41)

Silver chloride - AgCl (Cerargyrite) - 143.337 - Colorless - Cubic - D 5.56 (B45) - M.P. 457.5 (K95) - B.P. 1564 (K13) - R.I. 2.0710 (I8) - X-ray Lines 2.77, 1.96, 3.20 (A40)

Silver chromate - $Ag_2O \cdot CrO_3$ - 331.77 - Red or Dark Green - Monoclinic Acicular or Tabular Crystals - D 5.625^{25} (I8) - X-ray Lines 3.14, 3.02, 2.92 (A40)

Silver chromate, di- - $Ag_2O \cdot 2CrO_3$ - 431.78 - Ruby-Red - Triclinic - D 4.770^{26} (I8) - X-ray Lines 2.86, 1.61, 2.04 (A40)

Silver cyanide - AgCN - 133.90 - White - Hexagonal - D 3.95 (R12) - D.T. 320 (K79)

Silver fluoride - AgF - 126.88 - Yellow - Cubic - D 5.852^{16} (I8) - M.P. 435 (I8) - B.P. ~ 1150 (R68)

Silver fluoride,-di- - AgF_2 - 145.88 - Dark Brown - Rhombic - D 4.57-4.78 (R74) - M.P. 690 (W11) - D.T. 700 (<76 m.m.) (W11)

Silver fluoride, tri- - AgF_3 - 164.88 - Colorless Liquid - M.P. -5.95 (R84) - B.P. 57.13 (743 m.m.) (R84)

Silver germanate, thio- - $Ag_2S \cdot GeS_2$ (Nat. Argyrodite) - 384.56 - X-ray Lines 3.05, 2.68, 3.20 (A41)

Silver iron (III) oxide - $Ag_2O \cdot Fe_2C_3$ - 391.46 - X-ray Lines 2.57, 1.52, 1.37 (A41)

Silver iron (III) sulfide - $Ag_2S \cdot Fe_2S_3$ (Chalcopyrite) - 455.72 - Tetragonal - D 4.57 (X-ray) (B96) (S119)

Silver manganate, per- - $AgMnO_4$ - 226.81 - Black - Monoclinic - D 4.27^{28} (C59)

Silver molybdate - $Ag_2O \cdot MoO_3$ - 375.71 - Cubic - D 6.26 (X-ray) (F53) (S119) - X-ray Lines 2.80, 1.78, 1.64 (A41)

Silver nitrate - $AgNO_3$ - 169.888 - Colorless - Rhombic - D 4.352^{19} (I8) - M.F. 209.01 (L35) - T.P. 160 (K12) - D.T. 444 (I8) - R.I. α 1.729, β 1.744, γ 1.788 (W42) - X-ray Lines 3.00, 4.51, 4.08 (A40)

Silver nitrite - $AgNO_2$ - 153.888 - Colorless - Rhombic - D 4.493^{0} (B155) - D.T. 105 (B155) - X-ray Lines 3.06, 3.95, 1.97 (A40)

Silver oxalate - $Ag_2C_2O_4$ - 303.780 - Colorless - D 5.029^{4} (I8) - D.T. 140 (I8)

Silver oxide - Ag_2O - 231.760 - Brown - Cubic - D 7.143^{17} (I8) - D.T. 230 (I2) - X-ray Lines 2.72, 2.36, 1.67 (A40)

Silver oxide, per- - Ag_2O_2 - 247.760 - Gray - Cubic - D 7.44 (I8) - D.T. > 100 (I8)

Silver phosphate, meta- - $Ag_2O \cdot P_2O_5$ - 373.72 - Colorless - D 6.370 (I8) - M.P. 482 (I8)

Silver phosphate, pyro- - $2Ag_2O \cdot P_2O_5$ - 605.48 - Colorless - Radiating Crystals - D 5.306^{8} (I8) - M.P. 585 (I8)

Silver phosphate, ortho- - $3Ag_2O \cdot P_2O_5$ - 837.24 - Yellow - Cubic - D 6.370^{25} (I8) - M.P. 849 (I8) - X-ray Lines 2.68, 2.45, 1.66(A40)

Silver phosphate, hydrate - $Ag_2O \cdot P_2O_5 \cdot H_2O$ - 391.74 - Colorless - M.P. 235 (M29) - D.T. 240 (M29)

Silver phosphate, hydrate - $2Ag_2O \cdot P_2O_5 \cdot H_2O$ - 623.50 - Colorless - Hexagonal - D.T. 110 (I8) - R.I. ω 1.8036, ε 1.7983 (I8)

Silver rhenate - $Ag_2O \cdot Re_2O_7$ - 716.38 - Light Yellow - D 7.05^{25} (H77) - M.P. 430 (V15) - D.T. 455 (V15) -

Silver rhodium (VII) oxide - $Ag_2O \cdot Rh_2O_7$ - 549.58 - Tetragonal - D 5.36 (X-ray) (S119)

Silver selenide - Ag_2Se (Naumannite) - 294.72 - Black - Cubic - D 8.200 (H76) - M.P. 900 (K12) - T.P. 133 (K12)

Silver selenite - $Ag_2O \cdot SeO_2$ - 342.72 - Colorless - Needles - D 5.929 (I8)

Silver silicate, thio- - $3Ag_2S \cdot 2SiS_2$ - 927.86 - D 4.998^{25} (M59) - M.P. 758 (M59)

Silver silicate, thio- - $4Ag_2S \cdot SiS_2$ - 1083.50 - D 6.550 (M59) - M.P. 958 (M59)

Silver sulfate - Ag_2SO_4 - 311.826 - Grayish White - Rhombic - D 5.433 (W61) - M.P. 657 (K15) - T.P. 411 (L9); 652 (K79) - D.T. 1220 (.295 atm.)(K79) - R.I. α 1.7583, β 1.7748, γ 1.7852 (W61) - X-ray Lines 2.86, 3.17, 2.64 (A40)

Silver sulfide - Ag_2S (I) - 247.826 - Cubic - D 7.317 (I8) - M.P. 938 (K75) - X-ray Lines 2.43, 2.59, 2.07 (Form not defined)(A40)

Silver sulfide - Ag_2S (II) - 247.826 - Transition to I 586 (K75)

Silver sulfide - Ag_2S (Acanthite) - 247.826 - Gray-Black - Rhombic - D 7.326 (R12) - T.P. 177 (K80)

Silver sulfide - Ag_2S (Argentite) - 247.826 - Black - Cubic - D 7.317 (R12) - M.P. 825 (R12) - X-ray Lines 2.59, 2.83, 2.43 (A41)

Silver telluride - Ag_2Te (Hessite) - 343.37 - Gray - Cubic, Rhombic - D 8.49 (H74) - M.P. 959 (K84) - T.P. 145 (K84) - X-ray Lines 2.87, 2.30, 2.24 (A41)

Silver telluride - Ag_5Te_3 - 922.23 - M.P. 455 (Incong.) (K79) - T.P. 280, 415 (K79)

Silver telluride - Ag_3Te_2 - 578.86 - M.P. 465 (Incong.) (K84) - T.P. 286, 425 (K84)

Silver vanadate, pyro- - $2Ag_2O \cdot V_2O_5$ - 645.42 - Pale Yellow - M.P. 383 (I8) - X-ray Lines 2.88, 2.77, 2.56 (A40)

Silver vanadate - $3Ag_2O \cdot V_2O_5$ - 877.18 - M.P. 403 (L9)

Sodium - Na - 22.997 - Silvery White - Cubic - D 0.97^{20} (A20) - M.P. 97.7 (A20) - B.P. 892 (A20) - X-ray Lines 3.04, 1.76, 2.14 (A40)

Sodium aluminate - $Na_2O \cdot Al_2O_3$ - 163.93 - Colorless - M.P. >1700 (K4) - R.I. α 1.566, β 1.575, γ 1.580 (B139) - X-ray Lines 2.59, 2.55, 2.92 (A41)

Sodium aluminate - $Na_2O \cdot 12Al_2O_3$ (Miscalled 'B-Alumina') (R24) - 1285.27 - Colorless - Hexagonal - D 3.249 (R24) - D.T. 1300 (In Vacuum) (G3) - R.I. ω 1.668, ε 1.630 (R24) - X-ray Lines 1.400, 11.8, 1.59 (A40)

Sodium aluminate, hydrate - $Na_2O \cdot Al_2O_3 \cdot 3H_2O$ - 217.98 - Colorless - X-ray Lines 2.55, 2.30, 2.82 (A41)

Sodium aluminum antimonate - $Na_2O \cdot 2Al_2O_3 \cdot Sb_2O_5$ (Nat. Swedenborgite) - 589.39 - Colorless - Hexagonal - D 4.29 (L18) - R.I. ω 1.772, ε 1.770 (A22)

Sodium aluminum carbonate, hydrate - $2Na_2O \cdot 2Al_2O_3 \cdot 4CO_2 \cdot 4H_2O$ (Nat. Dawsonite) - 575.97 - Rhombic (L32) - D 2.47 (X-ray) (L32) (S119)

Sodium aluminum fluoride - $2NaF \cdot AlF_3$ (Nat. Chodnewite) - 167.96 - Tetragonal - D 3.0 (I8) - R.I. ω 1.349, ε 1.342 (I8)

Sodium aluminum fluoride - $3NaF \cdot AlF_3$ (Cryolite) - 209.96 - Colorless - Monoclinic - D 2.9482^{18} (R51) - M.P. 1020 (K79) - T.P. 56 (K79) - R.I. α 1.339, β 1.340, γ 1.340 (K96) - X-ray Lines 1.94, 2.75, 1.57 (A40)

Sodium aluminum fluoride - $3NaF \cdot 2AlF_3$ - 293.93 - Colorless - M.P. 740 (P73)

Sodium aluminum fluoride - $5NaF \cdot 3AlF_3$ (Chiolite) - 461.90 - Colorless - Tetragonal - D 3.005 (C39) - M.P. 725 (Incong.) (F6) - X-ray Lines 2.90, 5.17, 2.32 (A41)

Sodium aluminum hydroxy carbonate - $NaAl(OH)_2CO_3$ (Nat. Dawsonite) - 143.99 - Rhombic - D 2.4 (I8) - R.I. α 1.466, β 1.542, γ 1.596 (I8)

Sodium aluminum phosphate - $Na_2O \cdot Al_2O_3 \cdot 2P_2O_5$ - 447.85 - Colorless - Monoclinic - D 2.7 (O15)

Sodium aluminum phosphate - $3Na_2O \cdot 2Al_2O_3 \cdot 3P_2O_5$ - 815.74 - Colorless - D 2.1 (O15)

Sodium aluminum phosphate, hydrate - $Na_2O \cdot Al_2O_3 \cdot P_2O_5 \cdot H_2O$ (Nat. Fremontite) - 323.91 - Monoclinic - D 3.04 (I8) - R.I. α 1.594, β 1.603, γ 1.615 (I8)

Sodium aluminum phosphate, hydrate - $Na_2O\cdot 3Al_2O_3\cdot 2P_2O_5\cdot 4H_2O$ (Nat. Brazilianite) - 1281.74 - Monoclinic - D 3.06 (P65) - R.I. α 1.598, β 1.605, γ 1.617 (P65)

Sodium aluminum silicate - $Na_2O\cdot Al_2O_3\cdot 2SiO_2$(I) (Carnegieite) - 284.05 - Colorless - Triclinic - D 2.57 (I8) - M.P. 1526 (I8) - R.I. α 1.509, β -, γ 1.514 (B109) - X-ray Lines 4.29, 2.61, 1.50 (A41)

Sodium aluminum silicate - $Na_2O\cdot Al_2O_3\cdot 2SiO_2$ (II) (Nephelite) - 284.05 - Colorless - Hexagonal - D 2.619^{21} (B109) - Transition to I 1249-1259 (G67) - R.I. ω 1.537, ε 1.533 (B109) - X-ray Lines 3.01, 4.21, 3.83 (A41)

Sodium aluminum silicate - $Na_2O\cdot Al_2O_3\cdot 2SiO_2$ (Glass) - 284.05 - Colorless - R.I. 1.515 (T36)

Sodium aluminum silicate - $Na_2O\cdot Al_2O_3\cdot 3SiO_2$ (Nat. Metanatrolite) - 344.11 - Colorless - Monoclinic - R.I. α 1.483, β 1.485, γ 1.494 (H56)

Sodium aluminum silicate - $Na_2O\cdot Al_2O_3\cdot 4SiO_2$ (Nat. Analcime) - 404.17 - X-ray Lines 5.57, 3.42, 2.92 (A41)

Sodium aluminum silicate - $Na_2O\cdot Al_2O_3\cdot 4SiO_2$ (Nat. Jadeite) - 404.17 - Monoclinic - D 3.34 (I8) - M.P. 1050 (I8) - R.I. α -, β 1.654, γ - (I8) - X-ray Lines 2.94, 2.50, 2.84 (A41)

Sodium aluminum silicate - $Na_2O\cdot Al_2O_3\cdot 4SiO_2$ (Glass) - 404.17 - Colorless - D 2.43 (S95)

Sodium aluminum silicate - $Na_2O\cdot Al_2O_3\cdot 6SiO_2$ (Albite) - 524.29 - Colorless - Triclinic - D 2.61 (I8) - M.P. 1118 (G67) - T.P. 900 (G67) - R.I. α 1.525, β 1.529, γ 1.536 (I8) - X-ray Lines 3.20, 4.05, 3.66 (A40)

Sodium aluminum silicate - $Na_2O\cdot Al_2O_3\cdot 6SiO_2$ (Nat. Barbierite) - 524.29 - Tetragonal - R.I. α 1.5234, β 1.5294, γ 1.5305 (L9) - X-ray Lines 3.22, 4.11, 3.78 (A41)

Sodium aluminum silicate - $Na_2O\cdot Al_2O_3\cdot 6SiO_2$ (Glass) - 524.29 - Colorless - D 2.382 (D11) - R.I. 1.4892 (L16)

Sodium aluminum silicate - $3Na_2O\cdot 2Al_2O_3\cdot 4SiO_2$ - 630.10 - Cubic - D 2.63 (B100)

Sodium aluminum silicate - $4Na_2O\cdot 2Al_2O_3\cdot 4SiO_2$ - 692.10 - Cubic - D 2.78 (B100)

Sodium aluminum silicate chloride - $3Na_2O\cdot 3Al_2O_3\cdot 6SiO_2\cdot 2NaCl$ (Nat. Sodalite) - 969.07 - Colorless - Cubic - D $2.295^{14.8}$ (B125) - R.I. 1.484 (B125) - X-ray Lines 3.68, 2.60, 6.38 (A41)

Sodium aluminum silicate chloride - $3Na_2O\cdot 3Al_2O_3\cdot 54SiO_2\cdot 2NaCl$ (Nat. Marialite) - 3851.95 - Colorless - Tetragonal - D 2.56 (I8) - R.I. ω 1.539, ε 1.537 (I8)

Sodium aluminum silicate fluoride - $Na_2O\cdot Al_2O_3\cdot 9SiO_2\cdot 2NaF$ (Nat. Leifite) - 788.47 - Hexagonal D 2.57 (I8) - R.I. ω 1.518, ε 1.522 (I8)

Sodium aluminum silicate, hydrate - $Na_2O\cdot Al_2O_3\cdot 3SiO_2\cdot 2H_2O$ (Nat. Natrolite) - 380.14 - Colorless - Rhombic, Monoclinic - D 2.25 (I8) - R.I. α 1.480, β 1.482, γ 1.493 (I8)

Sodium aluminum silicate, hydrate - $Na_2O\cdot Al_2O_3\cdot 4SiO_2\cdot 2H_2O$ (Analcite) - 440.20 - Colorless - Cubic - D 2.25 (I8) - R.I. 1.472 (M92) - X-ray Lines 3.43, 5.59, 2.93 (A41)

Sodium aluminum silicate, hydrate - $Na_2O\cdot 3Al_2O_3\cdot 6SiO_2\cdot 2H_2O$ (Nat. Paragonite) - 764.21 - Colorless - Monoclinic - D 2.8 (I8) - R.I. α -, β 1.60, γ - (I8) - X-ray Lines 4.39, 2.52, 1.47 (A41)

Sodium aluminum silicate, hydrate - $2Na_2O\cdot Al_2O_3\cdot 6SiO_2\cdot H_2O$ (Nat. Ussingite) - 604.30 - Colorless - Triclinic - D 2.50 (I8) - R.I. α 1.504, β 1.508, γ 1.545 (I8) - X-ray Lines 2.95, 2.69, 6.35 (A41)

Sodium aluminum silicate, hydrate - $2Na_2O\cdot 3Al_2O_3\cdot 6SiO_2\cdot 7H_2O$ (Nat. Hydronephelite) - 916.28 - Colorless - Hexagonal - D 2.3 (I8) - R.I. ω 1.490, ϵ 1.502 (I8)

Sodium aluminum silicate, hydrate - $3Na_2O\cdot 2Al_2O_3\cdot 8SiO_2\cdot H_2O$ (Nat. Naujakasite) - 888.36 - Colorless - Monoclinic - D 2.615 (B84) - R.I. α -, β 1.537, γ - (B84)

Sodium aluminum silicate sulfate, hydrate - $4Na_2O\cdot 3Al_2O_3\cdot 6SiO_2\cdot SO_3\cdot 3H_2O$ (Nat. Vishnevite) - 1048.27 - D 2.328 (B32) - R.I. 1.489 (B32)

Sodium antimonate, hydrate - $Na_2O\cdot Sb_2O_5\cdot 6H_2O$ - 493.61 - X-ray Lines 3.99, 2.79, 2.41 (A41)

Sodium antimony fluoride - $NaF\cdot SbF_5$ - 258.76 - Rhombohedron - D 3.379^{18} (L13) - R.I. < 1.360 (L13) - X-ray Lines 4.10, 1.83, 2.05 (A41)

Sodium arsenate, meta- - $Na_2O\cdot As_2O_5$ - 291.82 - Rhombic - D 2.301 (R12) - M.P. 615 (A16)

Sodium arsenate, pyro- - $2Na_2O\cdot As_2O_5$ - 353.81 - D 2.21 (H59) - M.P. 850 (A16) - T.P. 688 (A16)

Sodium arsenate, ortho- - $3Na_2O\cdot As_2O_5$ - 415.80 - D 2.835 (I8) - M.P. 1260 (A16) - T.P. 410 (A16)

Sodium arsenate - $5Na_2O\cdot 3As_2O_5$ - 999.43 - M.P. 696 (Incong.) (K79)

Sodium arsenate, hydrate - $Na_2O\cdot As_2O_5\cdot 4H_2O$ (I) - 363.88 - Colorless - Monoclinic - $-H_2O$ at 70, $-2H_2O$ at 104.3 (G20)

Sodium arsenate, hydrate - $Na_2O\cdot As_2O_5\cdot 4H_2O$ (II) - 363.88 - Rhombic - D 2.535 (I8) - Transition to I 53.5 (G20) - R.I. α 1.538, β 1.554, γ 1.561 (I8)

Sodium arsenate, hydrate - $Na_2O\cdot As_2O_5\cdot 6H_2O$ - 399.91 - Rhombic - D 2.309 (I8) - $-2H_2O$ at 17.3 (G20) - R.I. α 1.479, β 1.502, γ 1.527 (I8)

Sodium arsenate, hydrate - $Na_2O\cdot As_2O_5\cdot 10H_2O$ - 471.97 - D 2.32 (J32) - R.I. α 1.479, β 1.502, γ 1.527 (J32)

Sodium arsenate, hydrate - $2Na_2O\cdot As_2O_5\cdot 15H_2O$ - 624.05 - Monoclinic - D 1.87 (I8) - R.I. α 1.462, β 1.466, γ 1.478 (I8)

Sodium arsenate, hydrate - $2Na_2O\cdot As_2O_5\cdot 25H_2O$ - 804.21 - Monoclinic - D 1.72 (I8) - M.P. 28 (I8) - R.I. α 1.445, β 1.450, γ 1.451 (I8)

Sodium arsenate, hydrate - $3Na_2O\cdot As_2O_5\cdot 24H_2O$ - 848.19 - Trigonal - D 1.759 (I8) - M.P. 86.3 (I8) - R.I. ω 1.457, ϵ 1.466 (I8)

Sodium barium aluminum silicate - $Na_2O\cdot BaO\cdot 2Al_2O_3\cdot 4SiO_2$ - 659.47 - Colorless - Rhombic - D 3.06^{18} (S67) - R.I. α 1.5695, β 1.5710, γ 1.5775 (S67)

Sodium barium carbonate - $Na_2CO_3\cdot BaCO_3$ - 303.37 - Colorless - M.P.740 (I8)

Sodium barium phosphate - $Na_2O\cdot 2BaO\cdot P_2O_5$ (I) - 510.67 - Colorless - Tetragonal - D 6.43 (X-ray) (K41)

Sodium barium titanium silicate - $2Na_2O \cdot BaO \cdot 2TiO_2 \cdot 10SiO_2$ (Nat. Leucosphenite) - 1037.75 - Monoclinic - D 3.1 (I8) - R.I. α 1.645, β 1.661, γ 1.688 (I8)

Sodium beryllium antimonate - $Na_2O \cdot 8BeO \cdot Sb_2O_5$ (Nat. Swedenborgite) - 585.67 - Colorless - Cubic - D 6.98 (X-ray) (P23) (S119)

Sodium beryllium antimonate - $Na_2O \cdot 8BeO \cdot Sb_2O_5$ (Nat. Swedenborgite) - 585.67 - Colorless - Hexagonal - D 6.46 (X-ray) (P23) (S119)

Sodium beryllium fluoride - $NaF \cdot BeF_2$ - 89.02 - Colorless - M.P. 365 (Incong.) (N35)

Sodium beryllium fluoride - $NaF \cdot 2BeF_2$ - 136.04 - Colorless - D.T. 280 (N35)

Sodium beryllium fluoride - $2NaF \cdot BeF_2$ - 131.01 - Colorless - Rhombic Monoclinic - D 2.471^{20} (O2) - M.P. 615 (N35) - T.P. 220, 330 (N35) - R.I.$\sim$ 1.2 (O2) - X-ray Lines 2.92, 2.66, 2.44 (A40)

Sodium beryllium phosphate - $Na_2O \cdot 2BeO \cdot P_2O_5$ (Nat. Beryllonite) - 253.99 - Rhombic - D 2.85 (I8) - R.I. α 1.552, β 1.558, γ 1.561 (I8)

Sodium beryllium silicate - $Na_2O \cdot BeO \cdot 2SiO_2$ (Nat. Chkalovite) - 207.13 - Colorless - Rhombic - D 2.661 (G22) - R.I. α 1.544, β -, γ 1.549 (G22)

Sodium beryllium silicate - $Na_2O \cdot BeO \cdot 4SiO_2$ (Glass) - 327.25 - Colorless - D 2.450 (L5) - R.I. 1.5096 (L5)

Sodium beryllium silicate - $3Na_2O \cdot 6BeO \cdot 14SiO_2$ - 1176.94 - Rhombic - D 2.552 (G7) - R.I. α -, β 1.532-1.545, γ - (G7)

Sodium beryllium silicate, hydrate - $Na_2O \cdot 2BeO \cdot 6SiO_2 \cdot H_2O$ (Nat. Eudidymite) - 490.41 - Monoclinic - D 2.55 (I8) - R.I. α 1.545, β 1.546, γ 1.551 (I8)

Sodium beryllium silicate, hydrate - $Na_2O \cdot 2BeO \cdot 6SiC_2 \cdot H_2O$ (Nat. Epididymite) - 490.41 - Rhombic - D 2.55 (I8) - R.I. α 1.565, β 1.569, γ 1.569 (I8)

Sodium bismuthate - $Na_2O \cdot Bi_2O_5$ - 559.99 - X-ray Lines 7.5, 4.06, 2.62 (A40)

Sodium bismuth (III) molybdate - $5Na_2O \cdot Bi_2O_3 \cdot 8MoO_3$ - 1927.57 - Tetragonal - D 4.24 (X-ray) (S58) (S119)

Sodium bismuth (III) sulfide - $Na_2S \cdot Bi_2S_3$ - 592.26 - Cubic - D 5.13 (X-ray) (B96) (S119)

Sodium bismuth (III) tungstate - $5Na_2O \cdot Bi_2O_3 \cdot 8WO_3$ - 2631.33 - Tetragonal - D 5.78 (X-ray) (B96) (S119)

Sodium borate - $Na_2O \cdot B_2C_3$ - 131.63 - Colorless - Hexagonal - D 2.464 (F3) - M.P. 966 (M85) - B.P. 1434 (C52) - R.I. ω 1.568, ε 1.457 (M85) - X-ray Lines 2.85, 2.64, 4.77 (A40)

Sodium borate - $Na_2O \cdot 2B_2O_3$ (I) - 201.27 - Colorless - M.P. 742 (M85)- B.P. 1575 (C52) - R.I. α 1.471, β 1.493, γ 1.528 (M85)

Sodium borate - $Na_2O \cdot 2B_2O_3$ (II) - 201.27 - Colorless - Transition to I 600 (M85) - R.I. α 1.50, β 1.523, γ 1.555 (M85)

Sodium borate - $Na_2O \cdot 2B_2O_3$ (III) - 201.27 - Colorless - Rhombic - D 2.279^{25} (J21) - Transition to I 725 (M85) - R.I. α 1.526, β 1.544, γ 1.576 (M85)

Sodium borate - $Na_2O \cdot 2B_2O_3$ (Glass) - 201.27 - Colorless - D 2.361^{25} (J21) - R.I. 1.516 (M85)

Sodium borate - $Na_2O \cdot 3B_2O_3$ - 270.91 - Colorless - Triclinic - M.P.766 (Incong.) (M85) - R.I. α 1.453, β 1.525, γ 1.551 (M85)

Sodium borate - $Na_2O \cdot 4B_2O_3$ - 340.55 - Colorless - Triclinic - M.P.816 (M85) - R.I. α 1.499, β 1.525, γ 1.582 (M85)

Sodium borate - $Na_2O \cdot 4B_2O_3$ -(Glass) - 340.55 - Colorless - R.I. 1.501 (M77)

Sodium borate - $Na_2O \cdot 7B_2O_3$ - 549.47 - Colorless - M.P. 688 (T4)

Sodium borate - $2Na_2O \cdot B_2O_3$ - 193.63 - Colorless - M.P. 625 (M85) - R.I. α 1.50, β 1.52, γ 1.50 (M85)

Sodium borate, chlor-, hydrate - $Na_2O \cdot B_2O_3 \cdot 2NaCl \cdot 4H_2O$ - 320.61 - Colorless - X-ray Lines 2.68, 2.01, 2.88 (A41)

Sodium borate, fluo- - $NaF \cdot BF_3$ (Ferrucite) - 109.82 - Colorless - Rhombic, Cubic - D 2.53 (X-ray) (K56) (S119) - T.P. 241 (V16) - R.I. α 1.301, β 1.301, γ 1.307 (L12)

Sodium borate, hydrate - $Na_2O \cdot B_2O_3 \cdot 4H_2O$ - 203.686 - Colorless - D 1.909 (M35)

Sodium borate, hydrate - $Na_2O \cdot B_2O_3 \cdot 8H_2O$ - 275.76 - Colorless - Monoclinic - D 2.09 (C51) - M.P. 53.5 (Incong.) (C51) - $-8H_2O$ at 100-140 (C51) - R.I. α 1.443, β 1.467, γ 1.481 (C51)

Sodium borate, hydrate - $Na_2O \cdot B_2O_3 \cdot 8H_2O$ - 275.76 - Colorless - Triclinic - D 1.743 (M35)

Sodium borate, hydrate - $Na_2O \cdot 2B_2O_3 \cdot 4H_2O$ (Kernite) - 273.33 - Colorless - Monoclinic - D 1.91^{20} (M34) - M.P. 151.5 (M34) - R.I. α 1.454, β 1.472, γ 1.488 (S7)

Sodium borate, hydrate - $Na_2O \cdot 2B_2O_3 \cdot 5H_2O$ (Tincalconite) - 291.36 - Colorless - Trigonal - D 1.880 (S9) - Transition to $Na_2O \cdot 2B_2O_3 \cdot 4H_2O$ 39 (M34) - Transition to $Na_2O \cdot 2B_2O_3 \cdot 2H_2O$ 88 (M36) - Transition to $Na_2O \cdot 2B_2O_3 \cdot H_2O$ 190 (M36) - R.I. ω 1.461, ε 1.474 (S9) - X-ray Lines 2.94, 2.19, 4.40 (A40)

Sodium borate, hydrate - $Na_2O \cdot 2B_2O_3 \cdot 10H_2O$ (Borax) - 381.44 - Colorless - Monoclinic - D 1.73 (I8) - Transition to $Na_2O \cdot 2B_2O_3 \cdot 4H_2O$ 58.5, Transition to $Na_2O \cdot 2B_2O_3 \cdot 5H_2O$ 60.8 (B79) - $-10H_2O$ at >400 (M36) - R.I. α 1.447, β 1.469, γ 1.472 (I8) - X-ray Lines 2.57, 2.84, 4.86 (A40)

Sodium borate, hydrate - $Na_2O \cdot 5B_2O_3 \cdot 10H_2O$ - 590.35 - Colorless - Prism - Transition to $Na_2O \cdot 5B_2O_3 \cdot 2H_2O$ 100 (R43) - X-ray Lines 2.57, 2.84, 4.86 (A40)

Sodium bromide - $NaBr$ - 102.913 - Colorless - Cubic - D 3.213^{25} (W61) - M.P. 766 (K79) - B.P. 1396 (K79) - R.I. 1.6439 (W61) - X-ray Lines 2.10, 2.98, 1.791 (A40)

Sodium calcium aluminate - $Na_2O \cdot 8CaO \cdot 3Al_2O_3$ - 816.45 - Colorless - Hexagonal - M.P. 1508 (Incong.) (B139) - R.I. α 1.702, β -, γ 1.710 (B139) - X-ray Lines 2.68, 1.558, 2.20 (G63)

Sodium calcium aluminate - $2Na_2O \cdot 3CaO \cdot 5Al_2O_3$ - 801.93 - Colorless - Hexagonal - M.P. > 1630 (B139) - R.I. 1.592 (Mean) (B139) - X-ray Lines 2.58, 4.20, 3.91 (A41)

Sodium calcium aluminate, hydrate - $Na_2O \cdot CaO \cdot 2Al_2O_3 \cdot 7H_2O$ (Nat. Gonnardite) - 448.07 - Rhombic - D 2.26 (L18) - R.I. α -, β 1.508, γ - (L18)

Sodium calcium aluminum borate, fluo-, hydrate - $Na_2Ca_3Al_4F_6B_6O_{17} \cdot 3H_2O$ (Nat. Johachidolite) - 760.08 - D 3.4 (I19) - R.I. α 1.715, β 1.720, γ 1.729 (I19)

Sodium calcium aluminum fluoride, hydrate - $NaF\cdot CaF_2\cdot AlF_3\cdot H_2O$ (Nat. Pachnolite) - 222.06 - D 2.99 (X-ray) (F15)

Sodium calcium aluminum fluoride, hydrate - $NaF\cdot CaF_2\cdot AlF_3\cdot H_2O$ (Nat. Thomsenolite) - 222.06 - D 2.97 (X-ray) (F15)

Sodium calcium aluminum phosphate, hydrate - $Na_2O\cdot 2CaO\cdot 6Al_2O_3\cdot 4P_2O_5\cdot 17H_2O$ - 1659.91 - Colorless - Monoclinic(?) - D 2.83 (L22) - R.I. α 1.584, β 1.598, γ 1.602 (L22)

Sodium calcium aluminum phosphate, hydrate - $2Na_2O\cdot CaO\cdot 6Al_2O_3\cdot 4P_2O_5\cdot 17H_2O$ (Nat. Wardite) - 1665.82 - Colorless - Tetragonal - D 2.81 (L18) - R.I. ω 1.590, ϵ 1.599 (L18)

Sodium calcium aluminum silicate - $Na_2O\cdot CaO\cdot Al_2O_3\cdot 2SiO_2$ (Glass) - 340.13 - Colorless - D 2.658 (S2) - R.I. 1.5585 (S2)

Sodium calcium aluminum silicate - $Na_2O\cdot CaO\cdot Al_2O_3\cdot 3SiO_2$ (Glass) - 400.19 - Colorless - D 2.612 (S2) - R.I. 1.5450 (S2)

Sodium calcium aluminum silicate - $Na_2O\cdot CaO\cdot Al_2O_3\cdot 4SiO_2$ (Glass) - 460.25 - Colorless - D 2.570 (S2) - R.I. 1.5355 (S2)

Sodium calcium aluminum silicate - $Na_2O\cdot 2CaO\cdot 3Al_2O_3\cdot 8SiO_2$ (Labradorite) - 479.97 - Colorless - X-ray Lines 3.22, 2.53, 1.82 (A41)

Sodium calcium aluminum silicate - $3Na_2O\cdot 27CaO\cdot 10Al_2O_3\cdot 28SiO_2$ (Sarkolith) - 4401.22 - Colorless - Tetragonal - R.I. ω 1.631, ϵ 1.615 (B145)

Sodium calcium aluminum silicate carbonate - $3Na_2O\cdot CaO\cdot 3Al_2O_3\cdot 6SiO_2\cdot CO_2$ (Cancrinite) - 952.25 - Colorless - M.P. 1253 (Incong.) (107 atm. CO_2) (K79)

Sodium calcium aluminum silicate carbonate, hydrate - $3Na_2O\cdot CaO\cdot 3Al_2O_3\cdot 6SiO_2\cdot 2CO_2\cdot H_2O$ (Cancrinite) - 1014.28 - Colorless - Hexagonal - R.I. ω 1.550, ϵ 1.519 (L11)

Sodium calcium aluminum silicate carbonate, hydrate - $4Na_2O\cdot 2CaO\cdot 4Al_2O_3\cdot 9SiO_2\cdot 2CO_2\cdot 3H_2O$ (Cancrinite) - 1450.50 - Hexagonal - R.I. ω 1.522, ϵ 1.499 (L10)

Sodium calcium aluminum silicate, hydrate - $Na_2O\cdot CaO\cdot 2Al_2O_3\cdot 10SiO_2\cdot 20H_2O$ (Nat. Faujasite) - 1282.87 - Cubic - D 1.92 (I8) - R.I. 1.48 (I8)

Sodium calcium aluminum silicate, hydrate - $Na_2O\cdot 2CaO\cdot 3Al_2O_3\cdot 9SiO_2\cdot 8H_2O$ (Nat. Pseudomesolite) - 1164.64 - Colorless - Triclinic - D 2.22 (I8) - R.I. α -, β 1.510, γ - (L18)

Sodium calcium aluminum silicate, hydrate - $Na_2O\cdot 2CaO\cdot 3Al_2O_3\cdot 9SiO_2\cdot 8H_2O$ (Nat. Mesolite) - 1164.64 - Colorless - Monoclinic - D 2.256 (H57) - R.I. α 1.505, β 1.505, γ 1.506 (I8)

Sodium calcium beryllium silicate, fluo- - $NaF\cdot CaO\cdot BeO\cdot 2SiO_2$ (Nat. Leucophanite) - 243.22 - Rhombic - D 2.96 (I8) - R.I. α 1.571, β 1.595, γ 1.598 (I8)

Sodium calcium beryllium silicate, fluo- - $NaF\cdot 2CaO\cdot 2BeO\cdot 3SiO_2$ (Nat. Meliphanite) - 384.38 - Tetragonal - D 3.01 (I8) - R.I. ω 1.612, ϵ 1.593 (I8)

Sodium calcium borate, hydrate - $Na_2O\cdot 2CaO\cdot 5B_2O_3\cdot 10H_2O$ (Nat. Probertite) - 702.51 - Colorless - Monoclinic - D 2.141 (L18) - R.I. α 1.517, β 1.525, γ 1.544 (L18)

Sodium calcium borate, hydrate - $Na_2O \cdot 2CaO \cdot 5B_2O_3 \cdot 16H_2O$ (Nat. Ulexite) - 810.61 - Colorless - Monoclinic - D 1.65 (L18) - R.I. α 1.491, β 1.504, γ 1.520 (L18) - X-ray Lines 2.69, 2.60, 2.07 (A41)

Sodium calcium carbonate - $Na_2CO_3 \cdot CaCO_3$ - 206.09 - Colorless - Hexagonal - D 2.540 (E13) - M.P. 720 (F68) - R.I. ω 1.547, ε 1.504 (E13) - X-ray Lines 2.62, 2.53, 2.08 (A41)

Sodium calcium carbonate - $Na_2CO_3 \cdot 2CaCO_3$ (Nat. Shortite) - 306.18 - Rhombic - D 2.629^{28} (F1) - M.P. 600 (Incong.) (F1) - T.P. 200 (F1) - R.I. α 1.531, β 1.555, γ 1.570 (F1)

Sodium calcium carbonate, hydrate - $Na_2CO_3 \cdot CaCO_3 \cdot 2H_2O$ (Nat. Pirssonite) - 242.13 - Rhombic - D 2.35 (I8) - M.P. 813 (I8) - R.I. α 1.504, β 1.509, γ 1.575 (I8) - X-ray Lines 2.50, 5.10, 2.65 (A41)

Sodium calcium carbonate, hydrate - $Na_2CO_3 \cdot CaCO_3 \cdot 5H_2O$ (Nat.Gaylussite) - 296.17 - Colorless - Monoclinic - D 1.99 (O8) - R.I. α 1.444, β 1.516, γ 1.523 (I8) - X-ray Lines 6.41, 3.18, 2.70 (A41)

Sodium calcium carbonate phosphate - $Na_2CO_3 \cdot CaCO_3 \cdot Ca_3(PO_4)_2$ (Carbonate Apatite) - 516.29 - Colorless - Hexagonal - R.I. ω 1.635, ε 1.626 (E8)

Sodium calcium magnesium aluminum silicate - $Na_2O \cdot 2CaO \cdot 2MgO \cdot Al_2O_3 \cdot 8SiO_2$ (Nat. Tuxtlite) - 837.21 - Monoclinic - D 3.27 (I8) - R.I. α 1.666, β 1.674, γ 1.688 (I8)

Sodium calcium phosphate - $Na_2O \cdot 2CaO \cdot P_2O_5$ (I) - 316.11 - Colorless - Hexagonal - D 2.17 (X-ray) (K41) (S119) - X-ray Lines 2.70, 2.61, 1.89 (Form not defined) (A41)

Sodium calcium phosphate - $Na_2O \cdot 2CaO \cdot P_2O_5$ (II) - 316.11 - Colorless - Rhombic - D 2.90 (X-Ray) (K41) (S119)

Sodium calcium phosphate - $Na_2O \cdot 3CaO \cdot P_2O_5$ - 372.19 - Colorless - Hexagonal - R.I. ω 1.623, ε 1.62 (L12)

Sodium calcium phosphate - $3Na_2O \cdot 3CaO \cdot 2P_2O_5$ - 638.14 - Monoclinic - D 2.1 (I8)

Sodium calcium silicate - $Na_2O \cdot CaO \cdot SiO_2$ - 178.13 - Colorless - Cubic - D 2.79 (W65) - R.I. 1.60 (W42) - X-ray Lines 2.667, 1.523, 1.877 (A40)

Sodium calcium silicate - $Na_2O \cdot CaO \cdot 3SiO_2$ (Glass) - 298.25 - Colorless - D 2.639 (S2) - R.I. 1.5493 (S2)

Sodium calcium silicate - $Na_2O \cdot CaO \cdot 4SiO_2$ (Glass) - 358.31 - Colorless - D 2.579 (S2) - R.I. 1.5363 (S2)

Sodium calcium silicate - $Na_2O \cdot CaO \cdot 5SiO_2$ (Glass) - 418.37 - Colorless - D 2.530 (S2) - R.I. 1.5264 (S2)

Sodium calcium silicate - $Na_2O \cdot CaO \cdot 6SiO_2$ (Glass) - 478.43 - Colorless - D 2.490 (H32) - R.I. 1.5188 (S2)

Sodium calcium silicate - $Na_2O \cdot 2CaO \cdot 3SiO_2$ - 354.33 - Colorless - Pseudocubic - M.P. 1284 (I8) - R.I. α 1.595, β -, γ 1.598 (M80) - X-ray Lines 2.644, 1.868, 3.360 (A40)

Sodium calcium silicate - $Na_2O \cdot 3CaO \cdot 6SiO_2$ - 590.59 - Colorless - Rhombic - M.P. 1047 (Incong.)(I8) - R.I. α 1.564, β 1.570, γ 1.579 (M80)

Sodium calcium silicate - $Na_2O \cdot 3CaO \cdot 6SiO_2$ (Glass) - 590.59 - Colorless - D 2.702 (M77) - R.I. 1.571 (M77)

Sodium calcium silicate - $2Na_2O \cdot CaO \cdot 3SiO_2$ - 360.25 - Colorless - Cubic - D 2.775 (W65) - M.P. 1141 (I8) - R.I. 1.571 (M80) - X-ray lines 2.668, 1.888, 1.540 (A40)

Sodium calcium silicate, fluo- - $NaF \cdot 2CaO \cdot SiO_2$ - 214.22 - Colorless - Needle - D 2.98 (B135)

Sodium calcium silicate, hydrate - $Na_2O \cdot 4CaO \cdot 6SiO_2 \cdot H_2O$ (Pectolite) - 664.69 - Monoclinic - D 2.73 (I8) - R.I. α 1.595, β -, γ 1.648 (K60) - X-ray Lines 2.89, 3.08, 1.70 (A41)

Sodium calcium sulfate - $Na_2SO_4 \cdot CaSO_4$ (Nat. Glauberite) - 278.21 - Colorless - Monoclinic - D 2.83 (I8) - M.P. 905 (K79) - R.I. α 1.515, β 1.532, γ 1.536 (I8) - X-ray Lines 3.13, 6.22, 2.66 (A41)

Sodium calcium sulfate - $4Na_2SO_4 \cdot CaSO_4$ - 704.39 - Colorless - M.P. 944 (K79)

Sodium calcium titanium silicate - $2Na_2O \cdot 4CaO \cdot 4TiO_2 \cdot 3SiO_2$ (Nat. Fersmannite) - 848.09 - Monoclinic - R.I. α 1.886, β 1.930, γ 1.939 (L12)

Sodium calcium uranium (VI) carbonate sulfate, fluo-, hydrate - $NaF \cdot 3CaO \cdot UO_3 \cdot 3CO_2 \cdot SO_3 \cdot 10H_2O$ (Nat. Schroeckingerite) - 888.57 - Greenish Yellow - R.I. α 1.489, β 1.541, γ 1.541 (J13) - X-ray Lines 7.2, 4.81, 2.88 (J13)

Sodium carbonate - Na_2CO_3 - 106.004 - Four modifications (M7) - M.P. 851 (K79) - T.P. 356, 486, 618 (M7) - R.I. α 1.410, β 1.537, γ 1.544 (W3) - X-ray Lines 2.36, 2.96, 2.60 (A40)

Sodium carbonate, bi- - $NaHCO_3$ (Nahcolite) - 84.015 - Colorless - Monoclinic - D 2.22 (L18) - D.T. 113.4 (760 m.m.) (K14) - R.I. α 1.380, β 1.500, γ 1.586 (L18) - X-ray Lines 2.95, 2.60, 2.19 (A41)

Sodium carbonate, hydrate - $Na_2CO_3 \cdot H_2O$ (Thermonatrite) - 124.020 - Rhombic - D 2.255 (P1) (C48) - M.P. 112.5 (Incong.) (760 m.m.)(W3) - R.I. α 1.420, β 1.506, γ 1.524 (L18) - X-ray Lines 2.76, 2.37, 2.67 (A40)

Sodium carbonate, hydrate - $Na_2CO_3 \cdot 7H_2O$ - 232.116 - Rhombic, Trigonal - D 1.51 (I8) - D.T. 35.1 (I8)

Sodium carbonate, hydrate - $Na_2CO_3 \cdot 10H_2O$ (Natrite) - 286.164 - Rhombic - D 1.446^{17} (D20) - Transition to $Na_2CO_3 \cdot 7H_2O$ at 31.85 (U3) - R.I. α 1.405, β 1.425, γ 1.440 (I8) - X-ray Lines 2.89, 5.3, 4.03 (A40)

Sodium carbonate, hydrate - $2Na_2CO_3 \cdot 5H_2O$ - 302.088 - Colorless - Rhombic - D 2.053 (P1) - R.I. α 1.435, β 1.492, γ 1.547 (P1)

Sodium carbonate, hydrate - $Na_2CO_3 \cdot NaHCO_3 \cdot 2H_2O$ (Trona) - 226.051 - Colorless - Monoclinic - D 2.13 (L18) - M.P. 195 (Incong.) (W4) - R.I. α 1.412, β 1.492, γ 1.540 (L18) - X-ray Lines 2.64, 3.05, 2.43 (A40)

Sodium carbonate, hydrate - $Na_2CO_3 \cdot 3NaHCO_3$ - 358.049 - Colorless - Needle - R.I. α 1.435, β -, γ 1.526 (C42) - X-ray Lines 2.96, 2.63, 2.43 (A41)

Sodium carbonate sulfate - $Na_2CO_3 \cdot 2Na_2SO_4$ (Burkeite) - 390.124 - Colorless - Rhombic - D 2.57 (F46) - R.I. α 1.450, β 1.490, γ 1.492 (F46) - X-ray Lines 2.78, 3.78, 2.58 (A41)

Sodium chlorate - $NaClO_3$ - 106.454 - Colorless - Cubic - D 2.49 (I8) - M.P. 248 (K79) - R.I. 1.5151 (I8) - X-ray Lines 2.94, 3.28, 1.76 (A40)

Sodium chlorate, per- - $NaClO_4$ - 122.454 - Colorless - Rhombic - D 2.499 (W58) - M.P. 482 (I8) - R.I. α 1.4606, β 1.4617, γ 1.4730 (W58) - X-ray Lines 3.53, 3.97, 2.95 (A40)

Sodium chloride - $NaCl$ - 58.454 - Colorless - Cubic (Rocksalt) - D 2.16360^{20} (H102) - M.P. 800.4 (R33) - B.P. 1445 (K79) - R.I. 1.5442 (I8) - X-ray Lines 2.814, 1.990, 1.259 (A40)

Sodium chromate - $Na_2O \cdot CrO_3$ - 162.00 - Yellow - Rhombic - D 2.73 (M52) - M.P. 392 (I8) - X-ray Lines 2.91, 2.73, 4.09 (A40)

Sodium chromate, di- - $Na_2O \cdot 2CrO_3$ - 262.01 - Orange - M.P. 356.7 (L39) - X-ray Lines 3.27, 4.69, 3.10 (A40)

Sodium chromium (III) phosphate - $Na_2O \cdot Cr_2O_3 \cdot 2P_2O_5$ - 497.93 - Green - Rhombic - D 3.0 (I8) -

Sodium chromium (III) sulfide - $Na_2S \cdot Cr_2S_3$ - 139.14 - Hexagonal (B98)

Sodium columbate - $Na_2O \cdot Cb_2O_5$ - 327.81 - Cubic (L15) - D 4.423 (L15) - X-ray Lines 2.74, 1.94, 1.73 (A41)

Sodium columbate - $3Na_2O \cdot Cb_2O_5$ - 451.80 - D 3.725^{22} (S113)

Sodium cyanate, seleno- - $NaCNSe$ - 127.98 - Colorless - Plates - D 2.490^{20} (H104)

Sodium cyanate, thio- - $NaCNS$ - 81.081 - Colorless - Rhombic - D 1.73^{20} (H104) - M.P. 323 (K15) - R.I. α 1.545, β 1.625, γ 1.695 (W42) - X-ray Lines 3.20, 3.49, 2.96 (A40)

Sodium cyanide - $NaCN$ - 49.015 - Colorless - Cubic - D 1.596^{20} (B77) - M.P. 562 (K15) - B.P. 1497 (K13) - R.I. 1.452 (F60) - X-ray Lines 2.94, 2.07, 1.69 (A40)

Sodium ferrate - See Sodium iron (III) oxide

Sodium fluoride - NaF - 42.00 - Colorless - Cubic - D 2.79 (I8) - M.P. 990 (B36) - B.P. 1705 (K79) - R.I. 1.3258 (S86) - X-ray Lines 2.33, 1.636, 1.335 (A40)

Sodium formate - $Na \cdot HCO_2$ - 68.015 - Colorless - Monoclinic - D 1.92 (I8) - M.P. 255 (K26) - X-ray Lines 2.79, 4.34, 3.39 (A40)

Sodium gallium sulfide - $Na_2S \cdot Ga_2S_3$ - 313.70 - Dark Yellow - Tetragonal - D 2.86 (I18) - M.P. 952 (I18) - R.I. >1.78 (I18)

Sodium germanate - $Na_2O \cdot GeO_2$ - 166.59 - Colorless - Monoclinic - D 3.31^{22} (S36) - M.P. 1083 (S38) - R.I. α -, β 1.59, γ - (S36)

Sodium germanate - $Na_2O \cdot 2GeO_2$ - 271.19 - M.P. 799 (S38)

Sodium germanate - $Na_2O \cdot 4GeO_2$ - 480.39 - M.P. 1052 (S38)

Sodium hydrogen sulfate - $Na_2SO_4 \cdot NaHSO_4$ - 262.131 - Colorless - D 2.422^{20} (L11) - X-ray Lines 3.98, 2.73, 2.90 (A41)

Sodium hydroxide - $NaOH$ - 40.005 - Colorless - Rhombic - 2.02 (K54) - M.P. 320 (K79) - T.P. 300 (K79) - B.P. 900 (K79) - R.I. α 1.457, β 1.470, γ 1.472 (M81) - X-ray Lines 2.35, 1.70, 1.65 (A40)

Sodium hydroxide, hydrate - $NaOH \cdot H_2O$ - 58.021 - Colorless - Rhombic - D 1.829 (L9) - M.P. 65.0 (M81) - R.I. α 1.435, β 1.470, γ 1.475 (M81) - X-ray Lines 2.95, 5.9, 2.70 (A41)

Sodium iodide - NaI - 149.92 - Colorless - Cubic - D 3.667 (I8) - M.P. 663 (K79) - B.P. 1300 (K79) - R.I. 1.7745 (W42) - X-ray Lines 3.22, 3.74, 2.29 (A40)

Sodium iron (III) fluoride - $3NaF \cdot FeF_3$ - 238.84 - Colorless - Cubic - D 2.00 (M55) - X-ray Lines 2.81, 3.97, 1.982 (A40)

Sodium iron (III) oxide - $Na_2O \cdot Fe_2O_3$ - 221.69 - Brown - Hexagonal - D 4.23 (G48) - M.P. 1345 (K59) - X-ray Lines 3.04, 2.64, 2.70 (A40)

Sodium iron (II, III) silicate - $Na_2O \cdot FeO \cdot Fe_2O_3 \cdot 5SiO_2$ (Nat. Riebeckite) - 593.84 - Monoclinic - D 3.44 (I8) - R.I. α -, β 1.687, γ - (I8)

Sodium iron (II, III) silicate - $Na_2O \cdot 2FeO \cdot Fe_2O_3 \cdot 6SiO_2$ (Nat. Crocidolite) - 725.75 - Monoclinic - D 3.2 (I8) - R.I. α -, β 1.70, γ - (I8)

Sodium iron (III) silicate - $Na_2O \cdot Fe_2O_3 \cdot 4SiO_2$ (Acmite) - 461.93 - Faint Yellow - Monoclinic - D 3.5 (I8) - M.P. 990 (Incong.) (B112) - α 1.776, β 1.819, γ 1.836 (W24) - X-ray Lines 3.01, 2.54, 2.92 (A41)

Sodium iron (III) silicate - $5Na_2O \cdot Fe_2O_3 \cdot 8SiO_2$ - 950.15 - Brown - Hexagonal - M.P. 838 (B117) - R.I. ω 1.609, ε 1.625 (B117)

Sodium iron (III) silicate - $5Na_2O \cdot Fe_2O_3 \cdot 8SiO_2$ (Glass) - 950.15 - Brown - R.I. 1.583 (B117)

Sodium iron (III) silicate - $6Na_2O \cdot 4Fe_2O_3 \cdot 5SiO_2$ - 1311.06 - M.P. 1091 (B117) - R.I. α -, β 1.96, γ - (B117)

Sodium lanthanum fluoride - $NaF \cdot LaF_3$ - 237.92 - Colorless - M.P. 920 (Incong.) (D18)

Sodium lanthanum fluoride - β_2-$NaF \cdot LaF_3$ - 237.92 - Hexagonal - D 4.68 (Z17)

Sodium lanthanum silicate - $Na_2O \cdot La_2O_3 \cdot 2SiO_2$ - 507.95 - Colorless - Hexagonal - D 3.92 (T48) - M.P. 1020 (T48) - R.I. ω 1.867, ε 1.840 (E14)

Sodium lanthanum tungstate - $5Na_2O \cdot La_2O_3 \cdot 8WO_3$ - 2491.17 - Tetragonal - D 5.41 (X-ray) (S59) (S119)

Sodium lead (II) silicate - $Na_2O \cdot 2PbO \cdot SiO_2$ - 568.47 - M.P. 840 (K79)

Sodium lead (II) silicate - $Na_2O \cdot 2PbO \cdot 3SiO_2$ - 688.59 - Monoclinic - M.P. 615 (K87)

Sodium lead (II) silicate - $Na_2O \cdot 2PbO \cdot 4SiO_2$ - 748.65 - Rhombic - M.P. 635 (Incong.) (K87) - R.I. α 1.744, β -, γ 1.782 (K87)

Sodium lead (II) silicate - $Na_2O \cdot 3PbO \cdot 6SiO_2$ (I) - 1091.98 - Tetragonal - M.P. 717 (K87) - R.I. α 1.704, β -, γ 1.707 (K87)

Sodium lead (II) silicate - $Na_2O \cdot 3PbO \cdot 6SiO_2$ (II) - 1091.98 - Rhombic - Transition to I 540 (K87) - R.I. α 1.719, β -, γ 1.744 (K87)

Sodium lead (II) silicate - $Na_2O \cdot 3PbO \cdot 7SiO_2$ - 1152.04 - Hexagonal - M.P. 725 (Incong.) (K87) - R.I. α 1.726, β -, γ 1.750 (K87)

Sodium lead (II) silicate - $3Na_2O \cdot 3PbO \cdot 11SiO_2$ - 1516.27 - M.P. 645 (Incong.) (K87) - R.I. α 1.617, β -, γ 1.681 (K87)

Sodium lithium aluminum fluoride - $3NaF \cdot 3LiF \cdot 2AlF_3$ (Nat. Cryolithionite) - 371.75 - Cubic - D 2.78 (I8) - R.I. 1.339 (I8)

Sodium lithium carbonate - $NaLiCO_3$ - 89.947 - Hexagonal - D 2.294 (E13) - M.P. 514 (E13) - R.I. ω 1.538, ε 1.406 (E13)

Sodium lithium silicate - $Na_2O \cdot Li_2O \cdot 2SiO_2$ - 211.99 - Colorless - Rhombic - M.P. 847 (Incong.) (K76) - R.I. α 1.552, β 1.557, γ 1.571 (K76)

Sodium lithium silicate - $Na_2O\cdot Li_2O\cdot 2SiO_2$ (Glass) - 211.99 - Colorless - R.I. 1.539 (Quenched) (K76)

Sodium lithium sulfate - $NaLiSO_4$ - 126.003 - Colorless - Hexagonal - D 2.369^{20} (G41) - M.P. ~ 525 (H10)

Sodium lithium tungstate - $3Na_2O\ Li_2O\cdot 4WO_3$ - 1143.54 - M.P. 511 (Incong.) (H80)

Sodium magnesium aluminum fluoride - $2NaF\cdot MgF_2\cdot AlF_3$ (Nat. Weberite) - 230.28 - Colorless - Monoclinic - D 2.96 (B89) - R.I. α 1.346, β 1.348, γ 1.350 (B89)

Sodium magnesium aluminum silicate - $Na_2O\cdot 6MgO\cdot Al_2O_3\cdot 7SiO_2$ - 826.27 - Colorless - Rhombic - R.I. α 1.623, β 1.6358, γ 1.6438 (Red) (L10)

Sodium magnesium carbonate - $Na_2CO_3\cdot MgCO_3$ - 190.33 - Colorless - Tetragonal - D 2.734 (E13) - M.P. 677 (1240 atm.) (E13) - R.I. ω 1.594, ε $<$ 1.54 (E13)

Sodium magnesium fluoride - $NaF\cdot MgF_2$ - 104.32 - Colorless - M.P. 1030 (G79)

Sodium magnesium phosphate - $Na_2O\cdot MgO\cdot P_2O_5$ - 244.27 - Colorless - Cubic - D 2.2 (I8)

Sodium magnesium phosphate - $Na_2O\cdot 2MgO\cdot P_2O_5$ - 284.59 - Colorless - D 2.5 (I8)

Sodium magnesium phosphate - $2Na_2O\cdot MgO\cdot P_2O_5$ - 306.27 - Cubic (?) - D 2.2 (O15)

Sodium magnesium silicate - $Na_2O\cdot MgO\cdot SiO_2$ - 162.37 - Colorless - Cubic - R.I. 1.523 (B103)

Sodium magnesium silicate - $Na_2O\cdot 2MgO\cdot 2SiO_2$ - 262.75 - Colorless - Monoclinic - R.I. α 1.641, β -, γ 1.654 (B103)

Sodium magnesium silicate - $Na_2O\cdot 2MgO\cdot 6SiO_2$ - 502.99 - Colorless - Monoclinic - R.I. α 1.540, β -, γ 1.546 (B103)

Sodium magnesium sulfate - $Na_2SO_4\cdot MgSO_4$ - 262.45 - Colorless - M.P. 670 (D33) - T.P. 625 (D33) - R.I. ω 1.650, ε 1.450 (D33)

Sodium magnesium sulfate - $3Na_2SO_4\cdot MgSO_4$ (Nat. Vanthoffite) - 546.57 - Colorless - Monoclinic (?) - D 2.69 (I8) - Transition to solid solution of same composition 489 (K79) - R.I. α 1.485, β 1.488, γ 1.489 (I8)

Sodium manganate, per- - $NaMnO_4$ - 141.93 - Purple - D 2.47^{25} (C58) - D.T. 170 (C58)

Sodium manganese (II) phosphate - $Na_2O\cdot MnO\cdot P_2O_5$ - 274.88 - D 2.9 (I8)

Sodium manganese (II) phosphate - $Na_2O\cdot 2MnO\cdot P_2O_5$ (Nat. Natrophilite) - 345.81 - Rhombic - D 3.41 (I8) - R.I. α 1.671, β 1.674, γ 1.684 (I8)

Sodium manganese (II) phosphate - $2Na_2O\cdot MnO\cdot P_2O_5$ - 336.88 - D 2.7 (I8)

Sodium molybdate - $Na_2O\cdot MoO_3$ - 205.94 - Colorless - Octahedra (B161) - D 3.28^{18} (B24)

Sodium molybdate - $Na_2O\cdot MoO_3$ (I) - 205.94 - Colorless - M.P. 687 (K15)

Sodium molybdate - $Na_2O\cdot MoO_3$ (II) - 205.94 - Colorless - Transition to I 621 (H80)

Sodium molybdate - $Na_2O\cdot MoO_3$ (III) - 205.94 - Colorless - Transition to II 580 (H80)

Sodium molybdate - $Na_2O\cdot MoO_3$ (IV) - 205.94 - Colorless - Transition to III 423 (H80)

Sodium molybdate, di- - $Na_2O\cdot 2MoO_3$ - 349.89 - Colorless - Needle - M.P. 612 (I8)

Sodium molybdenum phosphate, hydrate - $3Na_2O\cdot 5MoO_3\cdot P_2O_5\cdot 14H_2O$ - 1299.92 - Rhombic - R.I. α 1.596, β 1.641, γ 1.652 (I8)

Sodium neodymium silicate - $Na_2O\cdot Nd_2O_3\cdot 2SiO_2$ - 518.65 - Hexagonal - R.I. ω 1.889, ε 1.861 (E14)

Sodium neptunium (VI) acetate, oxy- - $NaNp^{237}O_2(O_2C_2H_3)_3$ - Cubic - D 2.556 (X-ray) (M4)

Sodium nitrate - $NaNO_3$ - 85.005 - Colorless - Trigonal - D 2.263^{23} (H91) - M.P. 305.5 (L38) - R.I. ω 1.5848, ε 1.3360 (I8) - X-ray Lines 3.03, 2.31, 1.89 (A40)

Sodium nitrate hydroxide - $NaNO_3\cdot NaOH$ - 125.010 - Colorless - M.P. 260 (R20)

Sodium nitrate hydroxide - $NaNO_3\cdot 2NaOH$ - 165.015 - Colorless - M.P. 260 (R20)

Sodium nitrite - $NaNO_2$ - 69.005 - Colorless - Rhombic - D 2.144(B155) - M.P. 284 (E22) - T.P. 158 (T44) - D.T. 370 (B155) - R.I. α 1.354, β 1.460, γ 1.648 (Z40) - X-ray Lines 2.97, 2.78, 2.02 (A40)

Sodium oxalate - $Na_2C_2O_4$ - 134.014 - Colorless - D 2.335 (H38) - R.I. α 1.410, β 1.528, γ 1.587 (H38) - X-ray Lines 2.81, 2.59, 2.32 (A40)

Sodium oxide - Na_2O - 61.994 - Colorless - Cubic - D 2.27 (I8) - M.P. 920 (B153) - D.T. 1275 (600 m.m.) (L40) - X-ray Lines 1.96, 2.78, 1.13 (A41)

Sodium oxide, per- - Na_2O_2 - 77.994 - Colorless - D 2.5 (I8) - M.P. 675 (B153) - D.T. 657 (760 m.m.) (C19) - X-ray Lines 2.55, 1.80, 2.35 (A40)

Sodium oxide, per-, hydrate - $Na_2O_2\cdot 8H_2O$ - 222.122 - Colorless - Hexagonal, Monoclinic - D 1.61 (K71) - D.T. 30 (I8)

Sodium phosphate, meta- - $Na_2O\cdot P_2O_5$ (I) - 203.95 - M.P. 627.6 (M83) - R.I. α 1.474, β 1.478, γ 1.480 (I5) - X-ray Lines 3.38, 3.83, 3.02 (A41)

Sodium phosphate, meta- - $Na_2O\cdot P_2O_5$ (II) - 203.95 - Rhombic - Transition to I 475-500 (P12) - R.I. α 1.498, β 1.510, γ 1.529 (I5) - X-ray Lines 2.86, 3.08, 4.98 (A41)

Sodium phosphate, meta- - $Na_2O\cdot P_2O_5$ (III) - 203.95 - Colorless - D 2.476 (I8) - Transition to II 400-425 (P12) - R.I. α 1.502, β -, γ 1.525 (P12) - X-ray Lines 2.80, 5.07, 3.12 (A41)

Sodium phosphate, meta- - $Na_2O\cdot P_2O_5$ (Glass) - 203.95 - Colorless - D 2.484^{20} (T5) - R.I. 1.4847 (I5)

Sodium phosphate, pyro- - $2Na_2O\cdot P_2O_5$ (I) - 265.95 - M.P. 985 (P12) - R.I. α 1.475, β 1.477, γ 1.496 (I5) - X-ray Lines 4.40, 2.72, 1.91 (Form not defined) (A40)

Sodium phosphate, pyro- - $2Na_2O\cdot P_2O_5$ (II) - 265.95 - Transition to I 545 (P12)

Sodium phosphate, pyro- - $2Na_2O\cdot P_2O_5$ (III) - 265.95 - Transition to II 518 (P12)

Sodium phosphate, pyro- - $2Na_2O\cdot P_2O_5$ (IV) - 265.95 - Transition to III 509 (P12)

Sodium phosphate, pyro- - $2Na_2O\cdot P_2O_5$ (V) - 265.95 - Colorless - D 2.45 (I8) - Transition to IV 398 (P12) - R.I. α 1.475, β -, γ 1.496 (P12)

Sodium phosphate, ortho- - $3Na_2O \cdot P_2O_5$ - 327.94 - Colorless - D 2.537$^{17.5}$ (I8) - M.P. 1340 (I8) - T.P. 700 (Z44) - X-ray Lines 2.55, 4.25, 2.70 (A40)

Sodium phosphate - $5Na_2O \cdot 3P_2O_5$ (I) - 735.85 - M.P. 622 (Incong.) (M83) - R.I. α 1.477, β 1.478, γ 1.504 (I5) - X-ray Lines 4.41, 2.72, 2.68 (A41)

Sodium phosphate - $5Na_2O \cdot 3P_2O_5$ (II) - 735.85 - Colorless - Transition to I 515 (P12) - R.I. α 1.470, β 1.477, γ 1.502 (I5) - X-ray Lines 2.68, 4.55, 2.60 (A41)

Sodium phosphate - $5Na_2O \cdot 3P_2O_5$ (Glass) - 735.85 - Colorless - R.I. 1.4814 (I5)

Sodium phosphate, boro- - $2Na_2O \cdot B_2O_3 \cdot P_2O_5$ - 335.59 - Colorless - M.P. 800 (K79)

Sodium phosphate, boro-, hydrate - $4Na_2O \cdot B_2O_3 \cdot P_2O_5 \cdot 36H_2O$ - 1108.15 - Colorless - X-ray Lines 2.78, 3.73, 2.86 (A41)

Sodium phosphate, fluo-, hydrate - $NaF \cdot PF_5 \cdot H_2O$ - 185.99 - D 2.369^{19} (L13)

Sodium phosphate, fluo-, hydrate - $NaF \cdot 3Na_2O \cdot P_2O_5 \cdot 19H_2O$ - 712.25 - Colorless - Cubic - D 2.217 (I8) - R.I. 1.452 (I8)

Sodium phosphate, fluo-, hydrate - $2NaF \cdot 3Na_2O \cdot P_2O_5 \cdot 24H_2O$ - 844.33 - Colorless - Cubic - D 2.216 (I8)

Sodium phosphate, hydrate - $Na_2O \cdot P_2O_5 \cdot H_2O$ - 221.97 - Colorless - Monoclinic, Needles - D 1.862 (I8) - D.T. 220 (I8) - R.I. ω 1.510, ε 1.517 (I5) - X-ray Lines 2.90, 3.38, 3.05 (A41)

Sodium phosphate, hydrate - $Na_2O \cdot P_2O_5 \cdot 2H_2O$ - 239.99 - Colorless - R.I. α 1.481, β 1.507, γ 1.517 (I5) - X-ray Lines 3.94, 3.18, 2.72 (A40)

Sodium phosphate, hydrate - $Na_2O \cdot P_2O_5 \cdot 4H_2O$ - 276.02 - Colorless - Rhombic - D 2.055 (I5) - M.P. 190 (Incong.) (I8) - R.I. α 1.456, β 1.485, γ 1.487 (I8)

Sodium phosphate, hydrate - $Na_2O \cdot P_2O_5 \cdot 4H_2O$ - 276.02 - Colorless - Triclinic - D 2.48 (G41) - R.I. ω 1.432, ε 1.441 (I5) - X-ray Lines 5.4, 3.39, 3.15 (Form not defined) (A40)

Sodium phosphate, hydrate - $Na_2O \cdot P_2O_5 \cdot 6H_2O$ - 312.05 - Colorless - Rhombic - D 1.910 (I5) - M.P. 60 (I8) - R.I. α 1.440, β 1.463, γ 1.482 (I8)

Sodium phosphate, hydrate - $Na_2O \cdot P_2O_5 \cdot 7H_2O$ - 330.07 - Colorless - Monoclinic - D 1.848 (I8) - R.I. α 1.460, β 1.465, γ 1.465 (I8)

Sodium phosphate, hydrate - $2Na_2O \cdot P_2O_5 \cdot H_2O$ - 283.97 - Colorless - R.I. α 1.483, β 1.499, γ 1.525 (I5) - X-ray Lines 2.80, 3.99, 3.81 (A40)

Sodium phosphate, hydrate - $2Na_2O \cdot P_2O_5 \cdot 5H_2O$ - 356.03 - Colorless - Hexagonal - D 1.848 (I8) - R.I. α 1.450, β 1.461, γ 1.477 (I5) - X-ray Lines 5.2, 4.61, 3.34 (A40)

Sodium phosphate, hydrate - $2Na_2O \cdot P_2O_5 \cdot 10H_2O$ - 446.11 - Colorless - Monoclinic - D 1.815 (I5) - R.I. α 1.450, β 1.453, γ 1.460 (I8) - X-ray Lines 4.35, 2.78, 3.68 (A40)

Sodium phosphate, hydrate - $2Na_2O \cdot P_2O_5 \cdot 11H_2O$ - 464.12 - Colorless - Rhombic - R.I. α -, β 1.443, γ - (I8)

Sodium phosphate, hydrate - $2Na_2O \cdot P_2O_5 \cdot 15H_2O$ - 536.19 - Colorless - Monoclinic - D 1.679 (I8) - R.I. α 1.441, β 1.442, γ 1.453 (I8)

Sodium phosphate, hydrate - $2Na_2O \cdot P_2O_5 \cdot 25H_2O$ - 716.35 - Colorless - Monoclinic - D 1.531 (I5) - M.P. 34.6 (I8) - R.I. α 1.432, β 1.436, γ 1.437 (I8) - X-ray Lines 5.4, 2.94, 2.71 (A40)

Sodium phosphate, hydrate - $3Na_2O \cdot P_2O_5 \cdot 2H_2O$ - 363.97 - Colorless - R.I. ω 1.497, ε 1.522 (I5)

Sodium phosphate, hydrate - $3Na_2O \cdot P_2O_5 \cdot 14H_2O$ - 580.17 - Colorless - R.I. α 1.462, β 1.470, γ 1.478 (I5)

Sodium phosphate, hydrate - $3Na_2O \cdot P_2O_5 \cdot 24H_2O$ - 760.33 - Colorless - Trigonal - D 1.63 (G41) - M.P. 73.4 (Incong.) (I8) - R.I. ω 1.4458 ε 1.4524 (W43) - X-ray Lines 2.86, 10.5, 2.69 (A40)

Sodium phosphate, hydrate - $3Na_2O \cdot 2P_2O_5 \cdot 33H_2O$ - 1064.43 - Colorless - M.P. 55 (I8)

Sodium phosphate, hydrate - $3Na_2O \cdot 3P_2O_5 \cdot H_2O$ - 629.88 - Colorless - X-ray Lines 2.84, 3.03, 2.60 (A40)

Sodium phosphate, hydrate - $5Na_2O \cdot 3P_2O_5 \cdot 12H_2O$ - 952.04 - Colorless - Triclinic - D 2.12 (B95) - R.I. α 1.449, β 1.450, γ 1.482 (I5)

Sodium plutonium (III) fluoride - $\beta_2\text{-}NaF \cdot PuF_3$ - 357.08 - Hexagonal - D 6.87 (Z17)

Sodium plutonium (IV) fluoride - $NaF \cdot PuF_4$ - 357.08 - Rhombic - D 6.03 (Z17)

Sodium praseodymium (IV) oxide - $Na_2O \cdot PrO_2$ - 234.91 - Cubic - D 4.60 (Z45)

Sodium praseodymium silicate - $Na_2O \cdot Pr_2O_3 \cdot 2SiO_2$ - 511.95 - Hexagonal - R.I. ω 1.889, ε 1.861 (E14)

Sodium rhenate, per- - $Na_2O \cdot Re_2O_7$ - 546.61 - Colorless - Hexagonal - D 5.24 (S68) - M.P. 414 (S68)

Sodium samarium silicate - $Na_2O \cdot Sm_2O_3 \cdot 2SiO_2$ - 530.97 - Hexagonal - R.I. ω 1.898, ε 1.867 (E14)

Sodium selenate - $Na_2O \cdot SeO_3$ - 188.95 - Colorless - Rhombic - D 3.10 (I8) - X-ray Lines 4.82, 2.87, 2.73 (A40)

Sodium selenate, hydrate - $Na_2O \cdot SeO_3 \cdot 10H_2O$ - 369.11 - Colorless - Monoclinic - D 1.58 (I8)

Sodium selenide - Na_2Se - 124.95 - Colorless - Cubic - D 2.6 (Z43) - M.P. > 875 (M14)

Sodium selenide - Na_2Se_2 - 203.91 - M.P. 495 (M14)

Sodium selenide - Na_2Se_3 - 282.87 - M.P. 313 (Incong.) (M14)

Sodium selenide - Na_2Se_4 - 361.83 - M.P. 290 (Incong.) (M14)

Sodium silicate - $Na_2O \cdot SiO_2$ - 122.05 - Colorless - Rhombic - D 2.614^{25} (B67) - M.P. 1089 (K73) - R.I. α 1.513, β 1.520, γ 1.528 (K73) - X-ray Lines 3.04, 2.40, 2.57 (A40)

Sodium silicate - $Na_2O \cdot SiO_2$ (Glass) - 122.05 - Colorless - D 2.570 (M77) - R.I. 1517 (M77)

Sodium silicate - $Na_2O \cdot 2SiO_2$ (I) - 182.11 - M.P. 874 (K79) - R.I. α 1.497, γ 1.508 (M78)

Sodium silicate - $Na_2O \cdot 2SiO_2$ (II) - 182.11 - Transition to I 707 (K77)

Sodium silicate - $Na_2O \cdot 2SiO_2$ (III) - 182.11 - Colorless - Rhombic - D 2.496^{25} (B73) - Transition to II 678 (K77) - T.P. 706 (K79) - R.I. α 1.500, β 1.510, γ 1.518 (M78)

Sodium silicate - $Na_2O \cdot 2SiO_2$ (Glass) - 182.11 - Colorless - D 2.489^{25} (B73) - R.I. 1.505 (G64)

Sodium silicate - $2Na_2O\cdot SiO_2$ (I) - 184.05 - M.P. 1120 (Incong.)(K73) - R.I. α 1.524, β -, γ 1.537 (K73)

Sodium silicate - $2Na_2O\cdot SiO_2$ (II) - 184.05 - Tablet - D 2.5 (D4) - Transition to I 960 (D4) - R.I. α -, β 1.536, γ - (M79)

Sodium silicate - $3Na_2O\cdot 2SiO_2$ - 306.09 - Colorless - Tablet - D 2.96^{22} (D4) - M.P. 1122 (D4) - R.I. α 1.524, β -, γ 1.529 (D4)

Sodium silicate, boro-, hydrate - $Na_2O\cdot B_2O_3\cdot 4SiO_2\cdot 2H_2O$ (Nat. Searlesite) - 407.90 - Colorless - Monoclinic - D 2.44 (F45) - R.I. α 1.515, β 1.533, γ 1.535 (F45)

Sodium silicate, fluo- - $2NaF\cdot SiF_4$ (Malladrite) - 188.05 - Colorless - Hexagonal - D 2.670 (I8) - R.I. ω 1.3125, ϵ 1.3089 (R2) - X-ray Lines 2.27, 1.79, 4.42 (A40)

Sodium silicate, hydrate - $Na_2O\cdot SiO_2\cdot 5H_2O$ - 212.13 - Colorless - Triclinic - D 1.749^{20} (B5) - M.P. 72.20 (B4) - R.I. α 1.447, β 1.454, γ 1.467 (W42) - X-ray Lines 3.33, 3.17, 2.71 (A41)

Sodium silicate, hydrate - $Na_2O\cdot SiO_2\cdot 6H_2O$ - 230.15 - Colorless - Monoclinic - D 1.807^{20} (B5) - M.P. 62.85 (B4) - R.I. α 1.465, β 1.473, γ 1.485 (W42)

Sodium silicate, hydrate - $Na_2O\cdot SiO_2\cdot 8H_2O$ - 266.18 - Colorless - Monoclinic - D 1.672^{20} (B5) - M.P. 48.35 (B4) - R.I. α 1.457, β 1.463, γ 1.465 (W42)

Sodium silicate, hydrate - $Na_2O\cdot SiO_2\cdot 9H_2O$ - 284.20 - Colorless - Rhombic - D 1.646^{20} (B5) - M.P. 47.85 (B4) - R.I. α 1.451, β 1.455, γ 1.460 (W42) - X-ray Lines 2.79, 3.83, 2.92 (A40)

Sodium silicate phosphate - $4Na_2O\cdot SiO_2\cdot 2P_2O_5$ - 591.96 - Colorless - M.P. 961 (S35)

Sodium strontium aluminum fluoride - $NaF\cdot 3SrF_2\cdot 3AlF_3$ (Nat. Jarlite) - 670.80 - Colorless - Monoclinic - D 3.93 (B88) - R.I. α 1.427, β 1.433, γ 1.435 (B88)

Sodium strontium aluminum fluoride - $NaF\cdot 3SrF_2\cdot 3AlF_3$ (Nat. Metajarlite) - 670.80 - D 3.781 (B88) - R.I. α -, β 1.432, γ - (B88)

Sodium strontium carbonate - $Na_2CO_3\cdot SrCO_3$ - 253.64 - Colorless - M.P. 750 (I8)

Sodium strontium phosphate - $Na_2O\cdot 2SrO\cdot P_2O_5$ (I) - 411.21 - Colorless - Tetragonal - D 4.00 (X-ray) (K41) (S119)

Sodium strontium phosphate - $Na_2O\cdot 2SrO\cdot P_2O_5$ (II) - 411.21 - Colorless - Hexagonal - D 2.74 (X-ray) (K41) (S119)

Sodium strontium titanium silicate - $Na_2O\cdot SrO\cdot TiO_2\cdot 2SiO_2$ (Nat. Lamprophyllite) - 365.64 - Rhombic - D 3.45 (G58) - R.I. α 1.745, β 1.754, γ 1.780 (L18)

Sodium sulfate - Na_2SO_4 (I) - 142.060 - Colorless - Hexagonal - M.P. 884 (I8) - X-ray Lines 2.78, 4.63, 2.64 (Form not defined) (A41)

Sodium sulfate - Na_2SO_4 (II) - 142.060 - Colorless - Transition to I 236, Transition to III 228 (K72) - R.I. $\alpha < 1.465$, β -, γ 1.480 (K72)

Sodium sulfate - Na_2SO_4 (III) - 142.060 - Colorless - Rhombic - D 2.697^{28} (K83) - Transition to I 247 (K72) - R.I. α -, β 1.480-1.485, γ - (K72) - X-ray Lines 2.78, 1.87, 4.66 (A40)

Sodium sulfate - Na_2SO_4 (IV) - 142.060 - Colorless - Monoclinic (?) - Transition to II 230, Transition to III 210 (K72) - R.I. $\alpha < 1.46$, β -, γ 1.480 (K72)

Sodium sulfate - Na_2SO_4 (V) (Thenardite) - 142.060 - Colorless - Rhombic - D 2.664^{25} (K83) - T.P. 235, 185 (K79) - R.I. α 1.467, β 1.473, γ 1.481 (W61) - X-ray Lines 2.82, 4.62, 3.10 (A41)

Sodium sulfate, pyro- - $Na_2O \cdot 2SO_3$ - 222.126 - Colorless - D 2.658^{25} (C5) - X-ray Lines 3.04, 3.38, 3.13 (A40)

Sodium sulfate, thio- - $Na_2S_2O_3$ - 158.126 - Colorless - Monoclinic - D 1.667 (I8) - X-ray Lines 4.14, 4.56, 3.06 (A41)

Sodium sulfate, bi- - $NaHSO_4$ - 120.071 - Colorless - Triclinic - D 2.476^{20} (O9) - M.P. 186 (K23) - R.I. α 1.43, β 1.46, γ 1.47 (B92).- X-ray Lines 3.40, 2.98, 2.77 (A40)

Sodium sulfate, chloro-, fluo-, - $2Na_2SO_4 \cdot NaCl \cdot NaF$ (Sulfohalite) - 384.57 - Colorless - Cubic - D 2.48 (X-ray) (S119)

Sodium sulfate, hydrate - $Na_2SO_4 \cdot 7H_2O$ - 268.17 - White - Rhombic, Tetragonal - $-7H_2O$ at 24.5 (K79)

Sodium sulfate, hydrate - $Na_2SO_4 \cdot 10H_2O$ (Nat. Mirabilite) - 322.220 - Colorless - Monoclinic - D 1.48 (I8) - R.I. α 1.394, β 1.396, γ 1.398 (I8) - X-ray Lines 3.10, 2.77, 4.62 (A41)

Sodium sulfate, hydrate - $Na_2SO_4 \cdot 10H_2O$ (Glauber Salt) - 322.220 - Colorless - Monoclinic - D 1.464 (I8) - T.P. 32.383 (R22) (R11) - R.I. α 1.396, β 1.4103, γ 1.4192 (R45)

Sodium sulfate, hydrate - $NaHSO_4 \cdot H_2O$ - 138.087 - Colorless - Monoclinic - D 2.117^{20} (O9) - X-ray Lines 3.55, 3.43, 5.2 (A40)

Sodium sulfate, thio-, hydrate - $Na_2S_2O_3 \cdot 5H_2O$ - 248.206 - Colorless - Monoclinic - D 1.69 (I8) - M.P. 48.0 (I8) - R.I. α 1.4886, β 1.5079, γ 1.536 (I8) - X-ray Lines 2.93, 5.4, 2.84 (A40)

Sodium sulfide - Na_2S - 78.060 - Colorless - Cubic - D 1.856 (I8) - M.P. 978 (P30)

Sodium sulfide - Na_2S_2 - 110.126 - Brownish Amber - M.P. 473.9 (P30)

Sodium sulfide - Na_2S_4 - 174.258 - Dark Yellow - Cubic - M.P. 284.8 (P30)

Sodium sulfide, bi- - $NaHS$ - 56.071 - Colorless - (I) Cubic, (II) Trigonal - D 1.79 (W37) - D.T. 400 (T25)

Sodium sulfite - Na_2SO_3 - 126.060 - Colorless - Hexagonal - D 2.633 (H22) - R.I. ω 1.565, ε 1.515 (W42) - X-ray Lines 2.72, 2.57, 1.87 (A40)

Sodium tantalate - $Na_2O \cdot Ta_2O_5$ - 503.75 - Cubic (?) - D 7.141 (X-ray) (Q2) - X-ray Lines 2.74, 1.74, 1.58 (A41)

Sodium telluride - Na_2Te - 173.60 - Colorless - D 2.90 (Z43) - M.P. 953 (P34)

Sodium thorium (IV) fluoride - $NaF \cdot 2ThF_4$ - 658.24 - Cubic - D 6.58 (Z17)

Sodium thorium (IV) fluoride - δ-$2NaF \cdot ThF_4$ - 392.12 - Hexagonal - D 5.37 (Z17)

Sodium thorium (IV) fluoride - β_2-$2NaF \cdot ThF_4$ - 392.12 - Hexagonal - D 5.46 (Z17)

Sodium thorium (IV) fluoride - $4NaF \cdot ThF_4$ - 476.11 - Colorless - Cubic - D 4.59 (Z17)

Sodium titanate - $Na_2O \cdot TiO_2$ - 141.89 - Needle (B10) - D 3.422 (B10) - M.P. 1030 (W23) - T.P. 287 (N12)

Sodium titanate - $Na_2O \cdot 2TiO_2$ - 221.79 - M.P. 985 (W23)

Sodium titanate - $Na_2O \cdot 3TiO_2$ - 301.69 - Colorless - Monoclinic - D 3.5 (I8) - M.P. 1128 (W23)
Sodium titanate - $4Na_2O \cdot 5TiO_2$ - 647.48 - Monoclinic (?) - R.I. α -, $\beta > 1.74$, γ - (N27)
Sodium titanium fluoride - $2NaF \cdot TiF_4$ - 207.89 - M.P. 700 (G31)
Sodium titanium silicate - $Na_2O \cdot 2TiO_2 \cdot 2SiO_2$ (Ramsayite) - 341.91 - Brown - D 3.43 (L18) - M.P. 624 (G32) - R.I. α 1.91, β 2.01, γ 2.03 (L18)
Sodium titanium silicate - $2Na_2O \cdot 5TiO_2 \cdot 4SiO_2$ - 763.73 - Prismatic - D 2.88 (G7) - R.I. α 1.623, β -, γ 1.655 (G7)
Sodium titanium silicate, hydrate - $Na_2O \cdot TiO_2 \cdot 6SiO_2 \cdot 3H_2O$ (Nat. Titanelpidite) - 556.30 - Rhombic - R.I. α 1.681, β 1.686, γ 1.698 (L12)
Sodium tungstate - $Na_2O \cdot WO_3$ (I) - 293.91 - M.P. 695.5 (G53)
Sodium tungstate - $Na_2O \cdot WO_3$ (II) - 293.91 - Transition to I 588.8 (G53)
Sodium tungstate - $Na_2O \cdot WO_3$ (III) - 293.91 - Rhombic - D 5.13^{20} (G53) - Transition to II 586 (G53) - R.I. α -, β 1.678, γ - (G53)
Sodium tungstate - $Na_2O \cdot 2WO_3$ - 525.83 - Rhombic - M.P. 738 (L49) - T.P. 547 (L49)
Sodium tungstate - $Na_2O \cdot 4WO_3$ - 989.67 - M.P. 784 (Incong.) (H80)
Sodium tungstate - $Na_2(WO_3)_5$ - 1205.59 - Cubic - D 7.283^{17} (I8)
Sodium tungsten phosphate - $Na_2O \cdot 2WO_3 \cdot P_2O_5$ - 667.79 - M.P. 850 (G41)
Sodium uranate - $Na_2O \cdot 3UO_3$ - 920.20 - Bronze Color - Rhombic (?) - D 6.912 (I8)
Sodium uranium (IV) fluoride - $NaF \cdot UF_4$ - 356.07 - Rhombic - D 5.81 (Z17)
Sodium uranium (IV) fluoride - α-$2NaF \cdot UF_4$ - 398.07 - Cubic - D 5.08 (Z17)
Sodium uranium (IV) fluoride - β_2-$2NaF \cdot UF_4$ - 398.07 - Hexagonal - D 5.74 (Z17)
Sodium uranium (IV) fluoride - γ-$2NaF \cdot UF_4$ - 398.07 - Rhombic - D 5.06 (Z17)
Sodium uranium (IV) fluoride - $3NaF \cdot UF_4$ - 440.07 - Tetragonal - D 4.49 (Z17)
Sodium vanadate, meta- - $Na_2O \cdot V_2O_5$ - 243.89 - Monoclinic, Needles (S75) - D 2.79 (I8) - M.P. 562 (I8)
Sodium vanadate, pyro- - $2Na_2O \cdot V_2O_5$ - 305.89 - Hexagonal - M.P. 654 (I8)
Sodium vanadate, ortho- - $3Na_2O \cdot V_2O_5$ - 367.88 - Colorless - M.P. ~ 866 (I8)
Sodium vanadate - $Na_2O \cdot V_2O_4 \cdot 5V_2O_5$ - 1137.39 - Rhombic (?) - M.P. ~ 800 (Incong.) (I8)
Sodium vanadate, hydrate - $3Na_2O \cdot V_2O_5 \cdot 20H_2O$ - 728.20 - Colorless - Hexagonal - R.I. ω 1.5398, ϵ 1.5475 (I8)
Sodium vanadate, hydrate - $3Na_2O \cdot V_2O_5 \cdot 20H_2O$ - 728.20 - Cubic - R.I. 1.5305 (I8)
Sodium vanadate, hydrate - $3Na_2O \cdot V_2O_5 \cdot 24H_2O$ - 800.27 - Hexagonal - D 1.62 (C32) - R.I. ω 1.5095, ϵ 1.5232 (I8)
Sodium yttrium fluoride - $NaF \cdot YF_3$ - 187.92 - D 4.21 (N39)

Sodium yttrium silicate - $Na_2O \cdot Y_2O_3 \cdot 2SiO_2$ - 407.95 - Colorless - Hexagonal - R.I. ω 1.832, ε 1.804 (E14)

Sodium zinc phosphate - $Na_2O \cdot ZnO \cdot P_2O_5$ - 285.33 - Colorless - Rhombic - D 3.1 (O15)

Sodium zinc phosphate - $2Na_2O \cdot ZnO \cdot P_2O_5$ - 347.33 - Colorless - Cubic - D 2.8 (I8)

Sodium zinc phosphate - $Na_2O \cdot 2ZnO \cdot P_2O_5$ - 366.71 - Colorless - Rhombic - D 3.3 (I8) - X-ray Lines 2.94, 2.52, 4.35 (A41)

Sodium zinc silicate, hydrate - $Na_2O \cdot ZnO \cdot SiO_2 \cdot H_2O$ - 221.45 - Colorless - X-ray Lines 2.56, 2.93, 2.62 (A40)

Sodium zinc uranyl acetate, hydrate - $NaZn(UO_2)_3(CH_3CO_2)_9 \cdot 6H_2O$ - 1538.08 - Monoclinic - R.I. α 1.475, β -, γ 1.480 (I7a)

Sodium zirconate - $Na_2O \cdot ZrO_2$ - 185.21 - Rhombic - D 4.0 (D4) - M.P. $\sim$ 1500 (Incong.) (D4) - R.I. α 1.720, β -, $\gamma > 1.80$ (D4)

Sodium zirconium silicate - $Na_2O \cdot ZrO_2 \cdot SiO_2$ - 245.27 - Rhombic - D 3.605^{24} (D4) - M.P. 1477 (Incong.) (D4) - R.I. α 1.741, β -, γ 1.790 (D4)

Sodium zirconium silicate - $Na_2O \cdot ZrO_2 \cdot 2SiO_2$ - 305.33 - Rhombic (?) - R.I. α 1.688, β -, γ 1.710 (D4)

Sodium zirconium silicate - $2Na_2O \cdot 2ZrO_2 \cdot 3SiO_2$ - 550.61 - Trigonal - D 2.880^{21} (D4) - R.I. ω 1.715, ε 1.692 (D4)

Sodium zirconium silicate, hydrate - $Na_2O \cdot ZrO_2 \cdot 3SiO_2 \cdot 2H_2O$ - 401.43 - Colorless - D 2.743 (X-ray) (B144)

Sodium zirconium silicate, hydrate - $Na_2O \cdot ZrO_2 \cdot 6SiO_2 \cdot 3H_2O$ (Nat. Elpidite) - 599.62 - Rhombic - D 2.58 (I8) - R.I. α 1.560, β 1.565, γ 1.574 (I8)

Strontium - Sr - 87.63 - Yellowish - Cubic - D 2.6^{20} (A20) - M.P. 770 (A20) (K79) - B.P. 1380 (A20) - X-ray Lines 3.50, 1.83, 3.03 (A41)

Strontium aluminate - $SrO \cdot Al_2O_3$ - 205.57 - White - Prism - M.P. 2015 (W18) - R.I. α 1.649, β -, γ 1.663 (T41)

Strontium aluminate - $SrO \cdot 2Al_2O_3$ - 307.51 - Colorless - Monoclinic - D 3.03 (x-ray) (L4) - R.I. α 1.614, β -, γ 1.640 (T41)

Strontium aluminate - $SrO \cdot 6Al_2O_3$ - 715.27 - White - Hexagonal - D 3.538 (T45) - R.I. ω 1.702, ε 1.860 (T45)

Strontium aluminate - $3SrO \cdot Al_2O_3$ - 412.83 - Cubic - D 3.50 (X-ray) (L4) - R.I. 1.728 (T41) - X-ray Lines 2.80, 1.61, 1.97 (A41)

Strontium aluminate - $3SrO \cdot 16Al_2O_3$ - 1941,93 - Hexagonal - D 4.22 (X-ray) (L4) (S119) - X-ray Lines 2.63, 2.48, 2.11 (A41)

Strontium aluminate, hydrate - $3SrO \cdot Al_2O_3 \cdot 6H_2O$ - 520.93 - Cubic - D 3.08 (M3) - D.T. 275 (M3) - R.I. 1.588 (M3) - X-ray Lines 5.35, 2.91, 3.48 (A41)

Strontium aluminum phosphate, hydrate - $2SrO \cdot 3Al_2O_3 \cdot 2P_2O_5 \cdot 7H_2O$ (Nat. Goyazite) - 923.11 - Trigonal - D 3.2 (I8) - R.I. ω 1.620, ε 1.630 (L12)

Strontium aluminum silicate - $SrO \cdot Al_2O_3 \cdot 2SiO_2$ - 325.69 - Colorless - Triclinic - D 3.118 (D25) - M.P. 1660 (D25) - R.I. α 1.574, β 1.582, γ 1.586 (E21)

Strontium arsenate - $3SrO \cdot As_2O_5$ - 540.71 - Colorless - Rhombic - D 4.60 (G82) - M.P. 1635 (G82)

Strontium arsenate, hydrate - $2SrO \cdot As_2O_5 \cdot H_2O$ - 455.10 - Colorless - Triclinic - D 4.035^{15} (S25) - Transition to $Sr_2As_2O_7$ 360 (H81) - R.I. α 1.635, β -, γ 1.67 (G6)

Strontium beryllium fluoride - $SrF_2 \cdot BeF_2$ - 172.65 - Colorless - Rhombic - D 3.736^{20} (R10)

Strontium borate - $SrO \cdot B_2O_3$ - 173.27 - Colorless - Needle - D 3.34• (M8) - M.P. 1100 (I8)

Strontium borate - $SrO \cdot 2B_2O_3$ - 242.91 - Colorless - Needle - M.P. 930 (I8)

Strontium borate - $2SrO \cdot B_2O_3$ - 276.90 - Colorless - Prism - M.P. 1130 (I8)

Strontium borate, fluo- - $SrF_2 \cdot 2BF_3$ - 261.27 - Colorless - Cubic and Diaxial - R.I. < 1.44 (D19)

Strontium carbide - SrC_2 - 111.65 - Black - Tetragonal - D 3.2 (R12) - T.P. 370 (B123)

Strontium carbonate - $SrCO_3$ (I) - 147.64 - Colorless - Hexagonal - D.T. 1250 (760 m.m.) (K14) - X-ray Lines 3.53, 2.45, 2.05 (A40)

Strontium carbonate - $SrCO_3$ (II) (Strontianite) - 147.64 - Colorless - Rhombic - D 3.7365^{25} (B49) - M.P. 1497 (60 atm. CO_2)(K79) - D.T. (1 atm. CO_2) 1289 (K79) - Transition to I 926 (K79) - R.I. α 1.5155, β 1.664, γ 1.666 (I8) - X-ray Lines 3.49, 2.42, 2.03 (Nat.) (A41)

Strontium cerium (IV) oxide - $SrO \cdot CeO_2$ - 275.76 - X-ray Lines 2.99, 2.11, 1.718 (A40)

Strontium chlorate - $Sr(ClO_3)_2$ - 254.54 - Colorless - Rhombic (also Monoclinic) - D 3.152 (I8) - M.P. 120 (Incong.) (I8) - R.I. α 1.567, β 1.605, γ 1.626 (I8)

Strontium chloride - $SrCl_2$ - 158.54 - Colorless - Cubic - D_0 3.052 (I8) - M.P. 873 (I8) - B.P. 1250 (S5) - R.I. 1.64986 (25° C)(W58)

Strontium chloride fluoride - $SrF_2 \cdot SrCl_2$ - 284.17 - Colorless - Tetragonal - D 4.18 (R12) - M.P. 962 (R12) - R.I. ω 1.651, ε 1.627 (M78)

Strontium chloride oxide - $SrCl_2 \cdot 2SrO$ - 365.80 - Colorless - Melts incong. (N17) - T.P. 1022 (N17)

Strontium chloride oxide - $4SrCl_2 \cdot SrO$ - 737.81 - Colorless - M.P. 995 (N17)

Strontium chromate - $SrO \cdot CrO_3$ - 203.64 - Pale Yellow - Monoclinic - D 3.895^{15} (I8) - X-ray Lines 3.26, 3.01, 1.97 (A40)

Strontium fluoride - SrF_2 - 125.63 - Colorless - Cubic - D 4.286 (W58) - M.P. 1190 (K79) - B.P. 2460 - R.I. 1.438082^{15} (M78) - X-ray Lines 3.37, 2.06, 1.75 (A40)

Strontium formate - $Sr(HCO_2)_2$ - 177.67 - Colorless - Rhombic - D 2.696 (A36) - M.P. 719 (I8) - R.I. α 1.543, β 1.552, γ 1.574 (A36) - X-ray Lines 5.4, 3.30, 3.01 (A40)

Strontium hafnate - $SrO \cdot HfO_2$ - 314.23 - Cubic - D 7.70 (X-ray) (H82)

Strontium hydroxide - $Sr(OH)_2$ - 121.65 - Colorless - D 3.305 (N32) - M.P. 535 (W53) - D.T. 775 (K79) - D.T. 710 (760 m.m.) (T3)

Strontium hydroxide, hydrate - $Sr(OH)_2 \cdot 8H_2O$ - 265.77 - Colorless - Tetragonal - D 1.90 (I8) - R.I. ω 1.4991, ε 1.4758 (I8) - X-ray Lines 2.02, 4.29, 2.76 (A40)

Strontium iron (III) oxide - $SrO\cdot Fe_2O_3$ - 263.33 - Hexagonal - D 5.0 (H66) - X-ray Lines 2.75, 1.589, 1.945 (A40)

Strontium molybdate - $SrO\cdot MoO_3$ - 247.58 - Colorless - Tetragonal - D 4.145 (I8) - R.I. $\omega,\varepsilon \sim 1.91$ (I8)

Strontium nitrate - $Sr(NO_3)_2$ - 211.65 - Colorless - Cubic - D 2.986 (I8) - M.P. 615 (W53) - R.I. 1.5878 (B29) (Y1) - X-ray Lines 4.50, 2.35, 2.24 (A40)

Strontium nitrate, hydrate - $Sr(NO_3)_2\cdot H_2O$ - 229.66 - Colorless - Cubic - R.I. 1.5888 (E18)

Strontium nitrate, hydrate - $Sr(NO_3)_2\cdot 4H_2O$ - 283.71 - Colorless - Monoclinic - D 2.2 (I8)

Strontium nitrite - $Sr(NO_2)_2$ - 179.65 - Needle - D 2.997^{0} (B155) - M.P. 276 (B155) - D.T. 350 (B155)

Strontium oxide - SrO - 103.63 - Colorless - Cubic, Rhombic - D 4.7 (Cubic) (I8) - M.P. 2430 (I8) - B.P. $\sim$ 3000 (M88) - R.I. 1.870 (H1) - X-ray Lines 2.97, 2.58, 1.82 (A40)

Strontium oxide, per- - SrO_2 - 119.63 - Colorless - Dimorphous - D 4.45 (B39) - D.T. 215 (760 m.m.) (T59) - X-ray Lines 2.52, 3.13, 2.00 (A40)

Strontium oxide, per-, hydrate - $SrO_2\cdot 8H_2O$ - 263.76 - Colorless - Tetragonal - D 1.98 (X-ray) (S119) - $-8H_2O$ at 100 (R12) - X-ray Lines 2.06, 1.95, 5.28 (A41)

Strontium phosphate, ortho- - $3SrO\cdot P_2O_5$ - 452.85 - Colorless - Rhombohedral - D.4.53 (X-ray) (Z11) - M.P. 1767 (K15) - X-ray Lines 2.91, 2.80, 2.02 (A41)

Strontium phosphate chloride - $3Sr_3(PO_4)_2\cdot SrCl_2$ - 1517.09 - Colorless - Hexagonal - D 4.87 (W49) - M.P. > 1560 (W49) - R.I. ω 1.650, ε 1.655 (W49)

Strontium phosphate fluoride - $3Sr_3(PO_4)_2\cdot SrF_2$ - 1484.18 - Colorless - Hexagonal - M.P. > 1580 (W49) - R.I. ω 1.621, ε 1.619 (W49)

Strontium phosphate, hydrate - $2SrO\cdot P_2O_5\cdot H_2O$ - 367.24 - Colorless - Rhombic - D 3.544 (I8) - R.I. α 1.608, β -, γ 1.625 (G7) - X-ray Lines 3.66, 2.87, 3.25 (A40)

Strontium phosphate, hydrate - $10SrO\cdot 3P_2O_5\cdot H_2O$ - 1480.20 - Colorless - X-ray Lines 2.89, 2.94, 1.81 (A41)

Strontium selenate - $SrO\cdot SeO_3$ - 230.59 - Transparent - Rhombic - D 4.25 (H44)

Strontium selenide - $SrSe$ - 166.59 - Colorless - Cubic - D 4.38 (H44) - R.I. 2.220 (H1)

Strontium silicate - $SrO\cdot SiO_2$ - 163.69 - Monoclinic, Pseudohexagonal - D 3.65 (I8) - M.P. 1580 (K79) - R.I. ω 1.599, ε 1.637 (E21)

Strontium silicate - $SrO\cdot SiO_2$-Glass - 163.69 - Colorless - D 3.537 (M77) - R.I. 1.632 (L16)

Strontium silicate - $SrO\cdot 2SiO_2$ (Glass) - 223.75 - Colorless - D 3.201 (M77) - R.I. 1.584 (M77)

Strontium silicate - $2SrO\cdot SiO_2$ - 267.32 - Monoclinic - D 3.84 (I8) (S104) - M.P. > 1700 (K79) - R.I. α 1.7275, β 1.732, γ 1.756 (E21) (S104)

Strontium silicate - $2SrO\cdot SiO_2$ - 267.32 - Colorless - Rhombic - D 4.52 (X-ray) (O3) (S119)

Strontium silicate, fluo-, hydrate - $SrF_2 \cdot SiF_4 \cdot 2H_2O$ - 265.72 - Colorless - Monoclinic - D $2.99^{17.8}$ (I8)

Strontium sulfate - $SrSO_4$ (I) - 183.70 - Colorless - Monoclinic - M.P. 1605 (Incong.) (G61) - X-ray Lines 2.97, 2.70, 2.03 (Form not defined) (A40)

Strontium sulfate - $SrSO_4$ (II) (Celestite) - 183.70 - Colorless - Rhombic - D 3.96 (I8) - Transition to I 1152 (G61) - R.I. α 1.6220, β 1.6237, γ 1.6309 (I8)

Strontium sulfide - SrS - 119.70 - Colorless, transparent - Cubic - D 3.70 (I8) - M.P. > 2000 (T32) - R.I. 2.107 (H1) - X-ray Lines 3.00, 2.12, 3.47 (A41)

Strontium telluride - SrTe - 215.24 - Cubic - D 4.83 (H1) - R.I. 2.408 (H1)

Strontium tin (IV) oxide - $SrO \cdot SnC_2$ - 254.33 - Cubic - D 6.39 (X-ray) (H82) - X-ray Lines 1.08, 0.95, 2.85 (A41)

Strontium titanate - $SrO \cdot TiO_2$ - 183.53 - Cubic - D 5.11 (X-ray)(H82) - X-ray Lines 2.76, 1.944, 1.589 (A40)

Strontium tungstate - $SrO \cdot WO_3$ - 335.55 - Colorless - Tetragonal - D 6.184 (I8) - X-ray Lines 3.22, 2.70, 2.00 (A41)

Strontium uranium (VI) oxide - $SrO \cdot UO_3$ - 389.70 - Yellow-green - Rhombohedral - D 7.62 (X-ray)(Z15)

Strontium zinc fluoride - $SrF_2 \cdot ZnF_2$ - 229.01 - Uniaxial - M.P. 727 (M78) - R.I. 1.455 (M78)

Strontium zirconate - $SrO \cdot ZrO_2$ - 226.85 - Cubic - D 5.48 (H82) - M.P. > 2700 (W21) - X-ray Lines 2.90, 1.667, 2.04 (A40)

Sulfur - S - 32.066 - Yellow - Rhombic - D 2.07^{20} (A20) - M.P. 113 (K79) - T.P. (Rhombic to Monoclinic) 97.5 (K80) - B.P. 444.60 (A20) (I8a) (K79) - R.I. α 1.958, β 2.0377, γ 2.2454 (L12) - X-ray Lines 3.85, 3.21, 3.10 (Form not defined) (A40)

Sulfur - S - 32.066 - Yellow - Monoclinic - D 1.95 (W42) - M.P. 119.3 (K80) - T.P. (Monoclinic to Rhombic) 78 (K80) - B.P. 444.60 (K79) (I8a) (A20) - R.I. α -, β 1.96, γ - (W42) - X-ray Lines 3.74, 3.15 3.94 (A41)

Sulfur fluoride - SF_2 - 70.07 - Colorless gas - B.P. -35 (L12)

Sulfur fluoride - SF_4 - 108.07 - Colorless gas - M.P. -124 (L12) - B.P. -40 (L12)

Sulfur fluoride - S_2F_{10} - 254.13 - Colorless Liquid - D 2.08^{0} (D14) - M.P. -92 (D14) - B.P. 29 (D14)

Sulfur fluoride - SF_6 - 146.07 - Colorless gas - D 1.878^{-50} (P32) - M.P. -50.8 (S32) - S.P. -63.5 (K13)

Sulfur oxide, di- - SO_2 - 64.066 - Colorless gas - D 1.928^{-191} (B58) - M.P. -75.46 (G25) - B.P. -10.02 (G25) - R.I. 1.410 (I8)

Sulfur oxide, tri- - SO_3 (I) - 80.066 - Colorless - Ice-Like - M.P. 44.8 (K13) - R.I. 1.4097 (M29)

Sulfur oxide, tri- - SO_3 (II) - 80.066 - Colorless - Asbesto-Like - D 1.97^{20} (O5) - M.P. 32.5 (K79) - B.P. 44.8 (K13)

Sulfur oxide, tri- - SO_3 (III) - 80.066 - Colorless - Asbesto-Like - M.P. 62.2 (2.29 atm.) (K79) - S.P. 44.8 (K79)

Tantalum - Ta - 180.88 - Silvery White - Cubic - D 16.6^{20} (A20) - M.P. 2996 (A20) - B.P. 6100 (A20) - X-ray Lines 1.335, 2.315, 0.872 (A40)
Tantalum antimonate - $Ta_2O_5 \cdot Sb_2O_3$ - 733.28 - Rhombic - D 7.54 (X-ray) (D21) (S119)
Tantalum carbide - TaC - 192.89 - M.P. 4150 (R12) - B.P. 5500 (R12) - X-ray Lines 2.56, 1.57, 1.34
Tantalum chloride - $TaCl_5$ - 358.16 - Colorless - D 3.68^{27} (I8) - M.P. 221 (I8) - B.P. 242 (I8)
Tantalum fluoride - TaF_5 - 275.88 - Colorless - Prisms - D 4.74 (I8) - M.P. 96.8 (I8) - B.P. 230 (K13)
Tantalum oxide - Ta_2O_5 - 441.76 - Colorless - Rhombic - D 8.015^{25} (L12) - M.P. 1875 (R65) - X-ray Lines 3.96, 2.81, 1.77 (A40)
Tantalum sulfide - TaS_2 - 245.01 - D 6.86^{25} (B62) - S.P. > 1000 (B62) - X-ray Lines 6.00, 2.95, 1.97 (A41)
Tantalum sulfide - TaS_3 - 277.08 - D 5.725^{25} (B62) - D.T. > 600 (B62)

Technetium - $_{43}Tc$ - Synthetic element with mass numbers 95, 96, 97, 99 and 1^1 for the known isotopes. (S45)
Technetium - $_{43}Tc^{99}$ - 98.913 (I7) - Silvery - Hexagonal - D 11.497 (X-ray) (M66) - M.P. 2700 (Computed) (A20)

Tellurium - Te - 127.61 - Silvery - Hexagonal - D 6.24^{20} (A20) - M.P. 449.8 (K78) - B.P. 1390 (K79) (A20) - R.I. ω 2.68, ε 3.07 (L10) - X-ray Lines 3.22, 2.34, 2.22 (A40)
Tellurium (II) chloride - $TeCl_2$ - 198.52 - Black - D 7.05 (R12) - M.P. 209 (R12) - B.P. 322 (W26)
Tellurium chloride - $TeCl_4$ - 269.44 - Colorless - D 3.26^{18} (B24) - M.P. 225 (S62) - B.P. 392 (K13)
Tellurium fluoride - TeF_6 - 241.61 - Colorless - D $2.67^{\text{M.P.}}$ (Liquid), $3.76^{\text{M.P.}}$ (Solid) (K46) - M.P. -37.8 (Y6) - T.P. -73.5 (Y6) - S.P. -38.6 (K13)
Tellurium oxide, di- - TeO_2 - 159.61 - Colorless - Tetragonal - D 5.66 (I8) - X-ray Lines 2.99, 3.40, 1.869 (Form not defined)(A40)
Tellurium oxide, di- - TeO_2 - 159.61 - Colorless - Rhombic - D 5.89 (I8) - R.I. α 2.00, β 2.18, γ 2.35 (All for Li-Lines) (I8)
Tellurium oxide, di- - TeO_2 - 159.61 - Colorless - M.P. 732.6 (L12)- Volatilize; drops solidify vitreous (K79) - S.P. 450 (I8)
Tellurium oxide, tri- - TeO_3 - 175.61 - Orange Yellow - D 5.075^{15} (M62) (M64)
Tellurium oxide, tri- - β-TeO_3 - 175.61 - Gray - D 6.21 (M64)
Tellurium oxide, tri-, hydrate - $TeO_3 \cdot H_2O$ - 193.63 - Colorless - D 3.44 (I8) - D.T. 160 (I8)
Tellurium oxide, tri-, hydrate - $TeO_3 \cdot 3H_2O$ - 229.66 - Colorless - Cubic - D 3.053 (I8) - Transition to H_2TeO_4 > 100 (K79)
Tellurium oxide, tri-, hydrate - $TeO_3 \cdot 3H_2O$ - 229.66 - Colorless - Monoclinic - D 3.071 (I8) - $-3H_2O$ at 300 (P20) - D.T. 300 (M46) - R.I. α 1.573, β 1.578, γ 1.630 (M46)

Terbium - Tb - 159.2 - Hexagonal (A20) - D 8.33 (X-ray) (A20) - M.P. 327 (K79)(A20) - X-ray Lines 2.72, 1.52, 1.80 (A41)

Terbium chloride - $TbCl_3$ - 265.6 - Colorless - Needles - D 4.35^{0} (I8) - M.P. 588 (I8)

Terbium nitrate, hydrate - $Tb(NO_3)_3 \cdot 6H_2O$ - 453.3 - Colorless - Monoclinic - M.P. 89.3 (I8)

Terbium oxalate - $Tb_2(C_2O_4)_3$ - 582.5 - Colorless - D 2.60 (M11)

Terbium oxide - Tb_2O_3 - 366.4 - Colorless - D 7.68 (M11)

Thallium - Tl - 204.39 - Grayish - Hexagonal - D 11.85^{20} (A20) - M.P. 303.5 (K79) - T.P. 232 (K79) - B.P. 1460 (A20) - X-ray Lines 2.62, 3.00, 1.73 (A40)

Thallium (I) aluminum fluoride - $TlF \cdot AlF_3$ - 307.36 - Colorless - Tetragonal - D 6.09 (B132)

Thallium (I) aluminum fluoride - $2TlF \cdot AlF_3$ - 530.75 - Colorless - Rhombic, needles (B134) - D 5.53 (B132) (B134)

Thallium (I) arsenic (III) sulfide - $Tl_2S \cdot As_2S_3$ (Nat. Lorandite) - 686.86 - Red - Monoclinic - D 5.53 (I8) - R.I. $\alpha > 2.72$, β 2.72, γ - (All for Li-Line) (I8) - X-ray Lines 3.57, 2.85, 2.95 (A41)

Thallium (I) beryllium fluoride - $2TlF \cdot BeF_2$ - 493.80 - Colorless - D 6.650^{20} (R10)

Thallium (I) borate - $Tl_2O \cdot B_2O_3$ - 494.42 - Colorless - M.P. 472 (C10)

Thallium (I) borate - $2Tl_2O \cdot B_2O_3$ - 919.20 - M.P. 434 (C10)

Thallium (I) borate - $3Tl_2O \cdot B_2O_3$ - 1343.98 - D.T. 370 (C10)

Thallium (I) borate, fluo- - $TlF \cdot BF_3$ - 291.21 - Rhombic, Cubic - D 4.74 (X-ray)(K56)(S119) - T.P. 205 (V16)

Thallium (I) carbonate - Tl_2CO_3 - 468.79 - Colorless - Monoclinic - D 7.11 (I8) - M.P. 273 (K15) - T.P. 228 (V16) - D.T. 368 (760 m.m.) (K14)

Thallium (I) carbonate nitrate - $Tl_2CO_3 \cdot TlNO_3$ - 735.19 - M.P. 214 (B136)

Thallium (I) carbonate nitrate - $Tl_2CO_3 \cdot 2TlNO_3$ - 1001.59 - M.P. 218 (B136)

Thallium chlorate, per- - $TlClO_4$ - 303.85 - Colorless - D_0 4.89 (R12) - M.P. 501 (R12) - X-ray Lines 3.82, 2.70, 2.30 (at 280°C)(A41)

Thallium (I) chloride - TlCl - 239.85 - Colorless - Cubic - D 7.00 (I8) - M.P. 427 (K15) - B.P. 807 (K13) - R.I. 2.247 (B14) - X-ray Lines 2.71, 3.82, 1.56 (A40)

Thallium (III) chloride - $TlCl_3$ - 310.76 - Colorless - Hexagonal - M.P. $\sim$ 25 (T27)

Thallium (I) cyanate - TlCNO - 246.41 - D 5.487^{20} (H104)

Thallium (I) cyanate, seleno- - TlCNSe - 309.37 - D 5.462^{20} (H104)

Thallium (I) cyanate, thio- - TlCNS - 262.47 - D 4.956^{20} (H104) - X-ray Lines 2.87, 1.82, 1.18 (A41)

Thallium (I) fluoride - TlF - 223.39 - Colorless - D 8.36^{20} (H31) - M.P. 327 (H31) - B.P. 655 (H31)

Thallium (III) fluoride - TlF_3 - 261.39 - Green - D 8.36 (H12) - M.P. 550 (H12)

Thallium (I) fluoride, acid- - $TlF \cdot HF$ - 243.40 - Cubic - D 5.01 (H23) - X-ray Lines 3.07, 3.49, 1.92 (A41)

Thallium (III) formate - $Tl(HCO_2)_3$ - 339.44 - Monoclinic - M.P. 95 (I8)

Thallium (I) hydroxide - $TlOH$ - 221.40 - Colorless or Yellow - Needle - D.T. 139 (760 m.m.) (I8)

Thallium (III) hydroxide - $Tl(OH)_3$ - 255.41 - Brown - Hexagonal - M.P. > 340 (I8)

Thallium (I) nitrate - $TlNO_3$ (I) - 266.40 - Cubic - M.P. 207 (K15) - B.P. 430 (I8)

Thallium (I) nitrate - $TlNO_3$ (II) - 266.40 - Hexagonal - Transition to I 143.5 (B127)

Thallium (I) nitrate - $TlNO_3$ (III) - 266.40 - Colorless - Rhombic (R30) - D 5.88 (X-ray) (R30) (S119) - Transition to II 61.0 (B127) - R.I. α 1.817, β -, γ - (B127)

Thallium (I, III) nitrate - $2TlNO_3\cdot Tl(NO_3)_3$ - 923.21 - Colorless - Prismatic - M.P. 150 (W31)

Thallium (III) nitrate, hydrate - $Tl(NO_3)_3\cdot 3H_2O$ - 444.46 - X-ray Lines 2.95, 4.40, 2.44 (A40)

Thallium (I) nitrite - $TlNO_2$ - 250.40 - Yellow - M.P. 182 (F16a)

Thallium (I) oxide - Tl_2O - 424.78 - Violet Black - D 9.52 (B23) - M.P. 300 (I8) - S.P. 1080 (600 m.m.) (L40)

Thallium (III) oxide - Tl_2O_3 - 456.78 - Brown and Black - Cubic - D 9.65^{21} (Brown), 10.19^{22} (Black) (I8) - M.P. 717 (K55) - X-ray Lines 1.56, 2.94, 1.82 (A41)

Thallium (I) phosphate, pyro- - $2Tl_2O\cdot P_2O_5$ - 991.52 - Monoclinic - D 6.79 (I8) - M.P. > 120 (I8)

Thallium (I) phosphate, ortho- - $3Tl_2O\cdot P_2O_5$ - 1416.30 - Colorless - Acicular - D 6.89^{10} (I8)

Thallium (I) phosphate, hydrate - $Tl_2O\cdot P_2O_5\cdot H_2O$ - 584.76 - M.P. 270 (I8)

Thallium (I) phosphate, hydrate - $Tl_2O\cdot P_2O_5\cdot 2H_2O$ - 602.77 - Monoclinic - D 4.72 (I8) - M.P. 167 (C64) - $-H_2O$ at 185, $-2H_2O$ at 400 (C64)

Thallium (I) rhenate, per- - $Tl_2O\cdot Re_2O_7$ - 909.40 - Rhombic - D 6.83 (H48) - M.P. 52 (V15) - T.P. 120 (V15)

Thallium (I) selenate - $Tl_2O\cdot SeO_3$ - 551.74 - Rhombic - D 6.875 (I8) - R.I. α 1.9493, β 1.9592, γ 1.9640 (I8)

Thallium (I) selenide - Tl_2Se - 487.74 - Metallic - Leaf - D 9.05^{28} (K55) - M.P. 340 (I8)

Thallium (I, III) selenide - $Tl_2Se\cdot Tl_2Se_3$ - 1133.40 - Tetragonal - D 8.175 (K30) - M.P. 338 (I8)

Thallium (I) silicate, fluo- - $2TlF\cdot SiF_4$ - 550.84 - Cubic - D 5.790 (X-ray) (K28) - X-ray Lines 1.15, 1.01, 1.04 (A41)

Thallium (I) silicate, fluo- - $2TlF_3\cdot 3SiF_4$ - 834.96 - D 5.72 (X-ray) (T1)

Thallium (I) sulfate - Tl_2SO_4 - 504.85 - Colorless - Rhombic - D 6.765 (T57) - M.P. 632 (I8) - R.I. α 1.8600, β 1.8671, γ 1.8853 (I8)

Thallium (I) sulfate - Tl_2SO_4 (Glass) - 504.85 - Colorless - D 6.77 (L7)

Thallium (I) sulfate, bi- - $TlHSO_4$ - 301.46 - D.T. 120 (I8)

Thallium (III) sulfate - $Tl_2(SO_4)_3$ - 696.98 - Rhombic - D 5.22^{15} (B24)

Thallium (I) sulfide - Tl_2S - 440.85 - Black - Hexagonal - D 8.40^{28} (V55) - M.P. 449 (K15)

Thallium (III) sulfide - Tl_2S_3 - 504.98 - Black - M.P. 260 (I13)
Thallium sulfide - Tl_2S_5 - 569.11 - Brick Red - M.P. 310 (I13)
Thallium (I) tellurate - $Tl_2O \cdot TeO_3$ - 600.39 - White - D 6.74^{16} (M29)
Thallium (I) telluride - Tl_2Te - 536.39 - M.P. 412 (I8)
Thallium (I, III) telluride - $Tl_2Te \cdot Tl_2Te_3$ - 1328.00 - Metallic Luster - Needle - D 8.42^{25} (K55)
Thallium telluride - Tl_3Te_2 - 868.39 - D 8.99 (K55) - M.P. 428 (M29)
Thallium (I) vanadate, meta- - $Tl_2O \cdot V_2O_5$ - 606.68 - Dark Gray - D 6.02^{17} (C14) - M.P. 424 (I8)
Thallium (I) vanadate, pyro- - $2Tl_2O \cdot V_2O_5$ - 1031.46 - Light Yellow - D 8.21 - 8.81 (C14) - M.P. 454 (I8)
Thallium (I) vanadate, ortho- - $3Tl_2O \cdot V_2O_5$ - 1456.24 - Brown - D 8.6^{17} (C14) - M.P. 566 (I8)
Thallium (I) vanadate - $3Tl_2O \cdot 2V_2O_5$ - 1638.14 - Yellow - D 8.59^{16} (C14)

Thorium - Th - 232.12 - Cubic - D 11.5^{20} (A20) - M.P. 1800 (A20) - B.P. 5200 (A20) - X-ray Lines 2.92, 2.53, 1.79 (A40)
Thorium (IV) chloride - $ThCl_4$ - 373.95 - Colorless - Rhombic - D 4.59 (I8) - M.P. 770 (F24) - B.P. 921 (F24) - X-ray Lines 7.2, 6.5, 4.12 (A40)
Thorium (IV) columbate - $5ThO_2 \cdot 16Cb_2O_5$ - 5573.72 - Rhombic - D 5.21^{17} (M29)
Thorium (IV) fluoride - ThF_4 - 308.12 - Colorless - Cubic - B.P. $>$ 1000 (R68)
Thorium (IV) molybdate - $ThO_2 \cdot 2MoO_3$ - 552.02 - Colorless - Tetragonal - D 7.5 (Z30)
Thorium (IV) nitrate - $Th(NO_3)_4$ - 480.15 - Plates - D.T. 161 (0.472 atm.)(K79); 500 (R12)
Thorium nitrate, hydrate - $Th(NO_3)_4 \cdot 12H_2O$ - 696.35 - Colorless - X-ray Lines 7.3, 4.82, 5.4 (A40)
Thorium (IV) oxalate - $Th(C_2O_4)_2$ - 408.16 - White - D 4.637^{16} (R12) - X-ray Lines 6.5, 7.9, 5.0 (A40)
Thorium (IV) oxide - ThO_2 (Thorianite) - 264.12 - Colorless - Cubic - D 9.69 (I8) - M.P. 3050 (W18) - R.I. 2.20 (I8) - X-ray Lines 1.98, 1.69, 1.14 (A41)
Thorium (IV) phosphate - $ThO_2 \cdot 2P_2O_5$ - 548.04 - Colorless - Rhombic - D 4.08^{16} (I8)
Thorium (IV) phosphate, hydrate - $3ThO_2 \cdot 2P_2O_5 \cdot 12H_2O$ - 1292.47 - Colorless - $-12H_2O$ at 850 (In Vacuum) (C18)
Thorium (IV) silicate - $ThO_2 \cdot SiO_2$ (Nat. Thorite) - 324.18 - Colorless - Tetragonal - D 5.3 (I8) - R.I. ω 1.80, ϵ 1.81 (W43) - X-ray Lines 2.58, 2.86, 1.67 (A41)
Thorium (IV) silicate, hydrate - $ThO_2 \cdot SiO_2 \cdot 4H_2O$ (Nat. Hydrothorite) - 396.24 - Cubic - R.I. 1.638 (L18)
Thorium (IV) sulfate - $Th(SO_4)_2$ - 424.25 - Colorless - D 4.37^{16} (B24) - X-ray Lines 4.77, 2.74, 3.30 (A40)
Thorium (IV) sulfate, hydrate - $Th(SO_4)_2 \cdot 8H_2O$ - 568.38 - Colorless - Monoclinic - R.I. α -, β 1.5168, γ - (W42)
Thorium (IV) sulfate, hydrate - $Th(SO_4)_2 \cdot 9H_2O$ - 586.40 - Colorless - Monoclinic - D 2.77 (I8) - X-ray Lines 6.9, 5.4, 6.25 (A40)

Thorium (IV) sulfide - ThS_2 - 296.25 - Lilac Brown (S108) - D 7.234 (P43) - M.P. 1925 (P43)
Thorium sulfide - TH_3S_7 - 920.82 - Deep Red (S108)
Thorium (IV) sulfide, oxy- - ThSO - 280.19 - Yellow - D 6.44 (I8)
Thorium (IV) zirconate - $ThO_2 \cdot ZrO_2$ - 387.34 - Needle - M.P. $>$ 2800 (R12) - R.I. 2.3 (R12)

Thulium - Tm(or Tu) - 169.4 - Hexagonal (A20) - D 9.35 (X-ray)(A20) - X-ray Lines 2.67, 1.49, 1.76 (A41)
Thulium chloride - $TmCl_3$ - 275.8 - Greenish Yellow - D 4.34^{25} (K37) - M.P. 821 (J18)
Thulium oxide - Tm_2O_3 - 386.8 - Colorless with a greenish tinge - Cubic - D 8.77 (X-ray) (Z7) - X-ray Lines 3.02, 1.85, 1.58 (A41)

Tin - Sn - 118.70 - Silvery White - Tetragonal - D 7.298 (A20) - M.P. 231.9 (A20) - T.P. 18, 145, 162 (K79) - B.P. 2270 (A20) - X-ray Lines 2.91, 2.79, 2.01 (A40)
Tin (II) chloride - $SnCl_2$ - 189.61 - Colorless - Rhombic - D 3.952^{25} (B53) - M.P. 247 (K15) - B.P. 652 (F23)
Tin (IV) chloride - $SnCl_4$ - 260.53 - Colorless Liquid - Cubic - D 2.226 (Liquid) (I8) - M.P. -30.2 (K79) - B.P. 115 (K79) - R.I. 1.512 (M29)
Tin (IV) fluoride - SnF_4 - 194.70 - Colorless - D 4.78 (I8) - B.P. 705 (I8)
Tin (II) iron (II) silicate - $SnO \cdot FeO \cdot SiO_2$ - 266.61 - M.P. 990 (K63)
Tin (II) iron (II) silicate - $3SnO \cdot 4FeO \cdot 6SiO_2$ - 1051.86 - M.P. 970 (K63)
Tin (II) oxalate - SnC_2O_4 - 206.72 - Colorless - D 3.56^{18} (I8) - X-ray Lines 4.62, 3.99, 3.37 (A40)
Tin (II) oxide - SnO - 134.70 - Gray, Brown, Green - Cubic - D 6.25 (S103) - M.P. 1040 (Incong.) (S85) - B.P. $\sim$ 1700 (S85) - X-ray Lines 2.96, 1.595, 1.482 (A40)
Tin (IV) oxide - SnO_2 (Cassiterite) - 150.70 - Yellow - Tetragonal, Hexagonal, Rhombic - D 7.000^{18} - M.P. 1625, Volatilize, Decomposes at M.P. (K79) - T.P. 400-425 (L24) - S.P. 1800-1900 (W16) - R.I. ω 1.9975, ε 2.0938 (H68) - X-ray Lines 3.40, 2.67, 1.77 (A40)
Tin (IV) oxide - SnO_2 (Wood tin) - 150.70 - X-ray Lines 1.76, 1.50, 1.21 (A41)
Tin (II) phosphate, meta- - $SnO \cdot P_2O_5$ - 276.66 - D 3.38^{22} (J1)
Tin (II) phosphate, pyro- - $2SnO \cdot P_2O_5$ - 411.36 - D 4.01^{18} (J1)
Tin (II) phosphate, ortho- - $3SnO \cdot P_2O_5$ - 546.06 - Colorless - D 3.823^{17} (J1) - X-ray Lines 3.98, 3.11, 4.39 (A40)
Tin (IV) phosphate,- $SnO_2 \cdot P_2O_5$ - 292.66 - Colorless - Cubic - D 3.957 (L44)
Tin (II) phosphate, hydrate - $SnO \cdot P_2O_5 \cdot 2H_2O$ - 312.69 - Rhombic - D 3.17^{23} (J1)
Tin (II) phosphate, hydrate - $2SnO \cdot P_2O_5 \cdot H_2O$ - 429.38 - D 3.48^{18} (J1)
Tin (II) selenide - SnSe - 197.66 - Steel Gray - D 6.18 (I8) - M.P. 861 (I8)
Tin (IV) selenide - $SnSe_2$ - 276.62 - Tin White - D 5.0 (I8) - M.P. 650 (M29)

Tin (IV) sulfate - $Sn(SO_4)_2$ - 310.83 - Colorless - D 3.45^{18} (B24)

Tin (II) sulfide - SnS - 150.77 - Gray - Cubic, Monoclinic - D 5.22^{25} (K55) - M.P. 880 (I8) - B.P. 1230 (I8) - X-ray Lines 2.83, 3.42, 3.24 (A40)

Tin (IV) sulfide - SnS_2 - 182.83 - Golden Yellow - Hexagonal - D 4.5 (I8) - D.T. ~ 600 (G9) - X-ray Lines 2.77, 5.9, 2.14 (A40)

Tin (IV) tantalate - $SnO_2 \cdot Ta_2O_5$ (Nat. Thoreaulite) - 592.46 - Monoclinic - D 7.8 (B160) - R.I. β 2.459 (B2)

Tin (II) telluride - SnTe - 246.31 - Gray - D 6.48 (I8) - M.P. 780 (I8)

Titanium - Ti-- 47.90 - White - Hexagonal - D 4.54^{20} (A20) - M.P.1820 (A20)(K79) - B.P. 5100 (A20) - X-ray Lines 2.241, 1.336, 2.556 (A40)

Titanium carbide - TiC - 59.91 - Metallic - Cubic - D 4.25 (R12) - M.P. 3140 (R12) - B.P. 4300 (R12) - X-ray Lines 2.66, 2.30, 1.63 (A41)

Titanium (III) chloride - $TiCl_3$ - 154.27 - Dark Violet - D.T. 440 (1 atm.) (K79)

Titanium chloride - $TiCl_4$ - 189.73 - Colorless - Liquid - D 1.7194^{25} (S3) - M.P. -25 (K79) - B.P. 136 (K13) - R.I. $1.61^{10.5}$ (I8)

Titanium fluoride - TiF_4 - 123.90 - Colorless - D 2.798^{21} (I8) - S.P. 284 (K79) - X-ray Lines 3.80, 1.90, 1.70 (A40)

Titanium oxide, mono- - TiO - 63.90 - Golden Yellow - D 4.93 (D6) - M.P. 1750 (D6) - T.P. 991 (N14) - X-ray Lines 2.12, 2.45, 1.50 (A41)

Titanium oxide, sesqui- - Ti_2O_3 - 143.80 - Trigonal - D 4.6 (I8) - M.P. 1900 (J40) - T.P. 200 (N14) - X-ray Lines 1.68, 1.85, 1.47 (A41)

Titanium oxide - Ti_3O_5 - 223.70 - T.P. 177 (N14)

Titanium oxide - $2Ti_2O_3 \cdot 3TiO_2$ - 527.30 - M.P. 1640 (I8)

Titanium oxide - TiO_2 (Brookite) - 79.90 - Colorless to Brown - Rhombic - D 4.17 (I8) - M.P. 1830 (B152) - D.T. 2227 (760 m.m.) (J40) - R.I. α 2.585, β 2.586, γ 2.699 (S18) - X-ray Lines 3.22, 1.68, 2.45 (A41)

Titanium oxide - TiO_2 (Rutile) - 79.90 - Colorless - Tetragonal - D 4.24 (C29) - Transition to Brookite 1300 (J40) - M.P. 1825 (K79) - R.I. ω 2.616, ε 2.903 (I8) - X-ray Lines 3.24, 1.68, 1.36 (A41)

Titanium oxide - TiO_2 (I) (Anatase) - 79.90 - Tetragonal - Transition to Rutile 915 (S17) - X-ray Lines 3.47, 1.88, 1.69 (Form not defined) (A41)

Titanium oxide - TiO_2 (II) (Anatase) - 79.90 - Colorless to Brown - Tetragonal - D 3.84 (I8) - Transition to I 642 (S17) - R.I. ω 2.560 ε 2.488 (W43)

Titanium phosphate - $TiO_2 \cdot P_2O_5$ - 221.86 - Colorless - Cubic - D 3.106 (X-ray) (L44)

Titanium selenide - $TiSe_2$ - 205.82 - Red - Hexagonal - D 5.29 (X-ray) (O6)

Titanium sulfate, oxy- - $TiOSO_4$ - 159.97 - Colorless - Rhomboidal - R.I. 1.80-1.89 (B87)

Titanium sulfide, mono- - TiS - 79.97 - Dark Brown - D 4.12 (B55)

Titanium sulfide, sesqui- - Ti_2S_3 - 192.00 - Grayish Brown - D 3.584 (P45)

Titanium sulfide - TiS_2 - 112.03 - Bronze Yellow - D 3.22^{20} (B55)

Titanium sulfide, tri- - TiS_3 - 144.10 - Graphite Appearance - D 3.22^{20} (B55)

Titanium telluride - $TiTe_2$ - 303.12 - Reddish - Hexagonal - D 6.24 (X-ray) (O6)

*Tungsten - W - 183.92 - Grayish Black - Cubic - D 19.3^{20} (A20) - M.P. 3410 (A20)(K79) - T.P. 650 (K79) - B.P. 5930 (A20) - X-ray Lines 2.23, 1.289, 0.997 (A40); also for β-W 2.25, 2.06, 1.34 (A41)

Tungsten carbide - WC - 195.93 - Gray - D 15.7^{18} (R12) - M.P. 2777 (R12) - B.P. 6000 (R12) - X-ray Lines 2.50, 1.87, 2.82 (A41)

Tungsten carbide - α-W_2C - 379.85 - Green - Hexagonal - D 16.06^{18} (R12) - M.P. 2857 (R12) - T.P. 2400 (L11) - B.P. 8000 (R12) - X-ray Lines 2.27, 1.49, 1.07 (A41)

Tungsten carbide - β-W_2C - 379.85 - X-ray Lines 1.35, 1.00, 2.35(A41)

Tungsten (IV) chloride - WCl_4 - 325.75 - Grayish Brown - D 4.624^{25} (B56)

Tungsten (V) chloride - WCl_5 - 361.21 - Black - Needle - D 3.875^{25} (B56) - M.P. 248 (I8) - B.P. > 300 (V13)

Tungsten (VI) chloride - WCl_6 - 396.66 - Dark Violet - Cubic (?) - D 3.542^{18} (H91) - M.P. 275 (I8) - B.P. 347 (V13)

Tungsten (VI) chloride oxide - WCl_2O_2 - 286.83 - Yellow - Tablets - M.P. 266 (L9) - D.T. 484 (475 m.m.) (K67)

Tungsten (VI) chloride oxide - WCl_4O - 341.75 - Red - Long Prismatic Needle - M.P. 211 (I8) - B.P. 232 (R14)

Tungsten (VI) fluoride - WF_6 - 297.92 - Colorless gas or liquid - D $3.427^{\text{B.P.}}$ (H45) - M.P. 2.3 (420 m.m.) (R70) - B.P. 17 (K79)

Tungsten (VI) fluoride oxide - WF_4O - 275.92 - Colorless - Plates - M.P. 110 (I8) - B.P. 187 (I8)

Tungsten (IV) oxide - WO_2 - 215.92 - Brown - Monoclinic (H6) - D 10.9 (B48) - M.P. 1280 (In N_2) (F61) - B.P. 1730 (A14) - X-ray Lines 3.44, 2.43, 1.73 (A41)

Tungsten (VI) oxide - WO_3 - 231.92 - Yellow - Triclinic - D 7.16 (G41) - M.P. 1473 (J3) - Dissoc. to W_2O_5 and O_2 2460 (Calc.)(K79) - B.P. 1430 (A14) - X-ray Lines 3.81, 2.65, 3.65 (A40)

Tungsten oxide - W_4O_{11} - 911.68 - X-ray Lines 3.78, 2.74, 3.62 (A41)

Tungsten (VI) oxide, hydrate - $WO_3 \cdot H_2O$ (Tungstite) - 249.94 - Yellow - Rhombic - D 5.5 (?) (I8) - -H_2O at 180-220 (K26) - R.I. α 2.09, β 2.24, γ 2.26 (I8) - X-ray Lines 3.47, 5.3, 2.55 (A41)

Tungsten oxide, hydrate - $WO_3 \cdot 3H_2O$ (Nat. Hydrotungstite) - 285.97 - -1 H_2O at 50-70 (K26) - R.I. α 1.70, β 1.95, γ 2.04 (K26)

Tungsten phosphate - $2WO_3 \cdot P_2O_5$ (Glass) - 605.80 - Dark Blue - D 4.927 (R56)

Tungsten phosphate - $3WO_3 \cdot P_2O_5$ (Glass) - 837.72 - Dark Blue - D 5.310 (R56)

---

* By action of the International Union of Chemistry, Amsterdam, Holland, September 9, 1949, the official name is wolfram.

Tungsten phosphate - $4WO_3 \cdot 3F_2O_5$ (Glass) - 1353.56 - Blue - D 4.632 (R56)

Tungsten phosphide - WP - 214.90 - Gray - Rhombic - D 12.30 (F2)

Tungsten phosphide - WP_2 - 245.88 - Black - D 9.17 (F2)

Tungsten (IV) sulfide - WS_2 (Nat. Tungstenite) - 248.05 - Grayish Black - Hexagonal - D 7.5 (I8) - D.T. > 1100 (In Vacuum) (G41) - X-ray Lines 6.2, 2.68, 2.28 (A41)

Tungsten telluride - WTe_2 - 439.14 - Gray Powder - Hexagonal - D 9.44^{15} (M73) - D.T. 735 (M73)

Uranium - U - 238.07 - Dark - Rhombic - D 18.7^{20} (A20) - M.P. 1150 (S73), 1130 (A20), 1125 (S31) - T.P. 665, 773 (S31) (M71) (D2), 645, 764 (D2) - X-ray Lines 2.25, 1.764, 2.535; 108, 0.907, 1.33 (A40)

Uranium (VI) arsenate, hydrate - $3UO_3 \cdot As_2O_5 \cdot 12H_2O$ (Nat. Troegerite) - 1304.22 - Monoclinic - D 3.3 (I8) - R.I. ω 1.624, ϵ 1.580, α 1.585, β 1.630, γ 1.630 (L11)

Uranium carbide - UC - 250.08 - Cubic - D 13.63 (X-ray) (R83)

Uranium carbide - UC_2 - 262.09 - Gray - Triclinic (R83) - D 11.28^{18} (R12) - M.P. 2260 (R12) - B.P. 4100 (R12)

Uranium carbide - U_2C_3 (R38) - 512.17

Uranium carbonate, dioxy- - UO_2CO_3 (Nat. Rutherfordine) - 330.08 - Yellow - Tetragonal - D 4.82 (L18) - R.I. α 1.72, β 1.75, γ 1.80 (I8)

Uranium (III) chloride - UCl_3 - 344.44 - Dark Red - Hexagonal - D 5.44 (Z19)

Uranium (IV) chloride - UCl_4 - 379.90 - Light Green - Cubic - D 4.860^{20} (H91) - M.P. 567 (V13) - B.P. 618 (V13)

Uranium (VI) chloride - UCl_6 - 450.81 - Black - Hexagonal - D 3.56 (X-ray) (Z16)

Uranium (III) deuteride - UD_3 - 244.11 - Cubic - D 11.11 (X-ray)(R82a)

Uranium (III) fluoride - UF_3 - 295.07 - Black (W7) - Hexagonal (W7)

Uranium (IV) fluoride - UF_4 - 314.07 - Green - Monoclinic (H19) - M.P. 1000 (R75) - R.I. α 1.552, β 1.584, γ 1.598 (H19)

Uranium (IV, V) fluoride - U_2F_9 - 647.14 - Cubic - D 7.06 (X-ray)(Z10)

Uranium (V) fluoride - α-UF_5 - 333.07 - Grayish to White - Tetragonal - D 5.81 (X-ray) (Z10) - T.P. (α to β) 125 (1.76 m.m. UF_6)(A33) - D.T. 175 (2 m.m. Hg) (G78)

Uranium (V) fluoride - β-UF_5 - 333.07 - Tetragonal - D 6.45 (X-ray) (Z10)

Uranium (VI) fluoride - UF_6 - 352.07 - Colorless or Slight Yellow - Monoclinic - D 4.68^{21} (I8) - M.P. 69.2 (1490 m.m.)(R75) - S.P. 56.5 (1 atm.)(W28) - D.T. > 400 (G78)

Uranium (VI) fluoride, dioxy- - UO_2F_2 - 308.07 - Rhombohedral - D 6.24 (Z14)

Uranium (VI) formate, dioxy-, hydrate - $UO_2(CHO_2)_2 \cdot H_2O$ - 378.12 - Yellow - D 3.69^{19} (I8) - -H_2O at 110 (469) (I8)

Uranium (III) hydride - UH_3 - 241.09 - D 10.9 (B157)

Uranium nitrate, dioxy- - $UO_2(NO_3)_2$ - 394.09 - Yellow - D.T. 160 (540 m.m.) (M57)

Uranium nitrate, dioxy-, hydrate - $UO_2(NO_3)_2 \cdot 3H_2O$ - 448.13 - Yellow - Triclinic - M.P. 120 (I8)

Uranium nitrate, dioxy-, hydrate - $UO_2(NO_3)_2 \cdot 6H_2O$ - 502.18 - Yellow - Rhombic - D 2.742 (P22) - M.P. 60.2 (G41) - R.I. α -, β 1.4967, γ - (I8) - X-ray Lines 5.7, 4.33, 6.6 (A40)

Uranium nitride - UN - 252.08 - Cubic - D 14.32 (X-ray) (R83)

Uranium nitride - U_2N_3 - 518.16 - Cubic - D 11.24 (X-ray) (R83)

Uranium oxalate, dioxy- - $UO_2C_2O_4$ - 358.09 - D 2.98 (I8)

Uranium (II) oxide - UO - 254.07 - Cubic (R83)

Uranium (IV) oxide - UO_2 - 270.07 - Brown to Black - Cubic - D 10.75^{28} (B68), 10.96 (R83) - M.P. 2280 (F61)

Uranium oxide - $UO_{2.25}$ - 274.07 - D 10.04 (X-ray) (R83)

Uranium oxide - $UO_{2.34}$ (I) - 275.51 - D 10.00 (G75) - Transition to II 200-250 (G75)

Uranium oxide - $UO_{2.34}$ (II) - 275.51 - D 11.05 (G75) - Transition to I 200-250 (G75)

Uranium oxide - U_3O_7 - 264.85 - Bluish Black - Structure similar to UO_2 (J30)

Uranium (V) oxide - U_2O_5 - 556.14 - Rhombic - D 8.35 (X-ray) (R83)

Uranium (VI) oxide - UO_3 - 286.07 - Orange - Cubic - D 6.04^{25} (B68) - Transition to U_3O_8 800 (1 atm. O_2) (F60) - D.T. 700 (F60)

Uranium (VI) oxide - UO_3 (New Form) (K6a) - 286.07 - Brick Red - D.T. 700 (Complete) (K6a)

Uranium (IV, VI) oxide - U_3O_8 (Pitchblend) - 842.21 - Black - Rhombic (G74) - D 8.34 (G74) - Decomposition to UO_2 1300 (B68) - X-ray Lines 4.15, 3.43, 2.64 (A41)

Uranium (VI) oxide, hydrate - $UO_3 \cdot 2H_2O$ (Nat. Schoepite) - 322.10 - Yellow - Rhombic - D 4.96 (L18) - -1 H_2O at 100, -2H_2O at 300 (K79) - R.I. α 1.690, β 1.714, γ 1.735 (L18)

Uranium (VI) oxide, hydrate - $UO_3 \cdot xH_2O$ - Yellow - Rhombic - R.I. α 1.70, β 1.79, γ 1.793 (S16)

Uranium (VI) oxide, hydrate - $3UO_3 \cdot 7H_2O$ (Nat. Schoepite) - 984.32 - Rhombic - R.I. α 1.690, β 1.714, γ 1.735 (L12)

Uranium (VI) oxide, hydrate - $5UO_3 \cdot 9\frac{1}{2}H_2O$ (Nat. Paraschoepite) - 1601.50 - Yellow - Rhombic - R.I. α 1.705, β 1.760, γ 1.770 (S16)

Uranium oxide, hydrate - $UO_4 \cdot 2H_2O$ - 338.10 - Yellowish White - D.T. 115 (I8)

Uranium (IV) phosphate, dioxy- - $UO_2 \cdot P_2O_5$ - 412.03 - Slight Rose - Cubic - D 4.288 (X-ray) (P37)

Uranium (VI) phosphate, dioxy- - $UO_2 \cdot 2P_2O_5$ - 553.99 - Green - Rhombic - D 3.9 (I8)

Uranium (VI) phosphate, hydrate - $3UO_3 \cdot P_2O_5 \cdot 6H_2O$ (Nat. Phosphoruranylite) - 1108.27 - Yellow - Monoclinic - R.I. α 1.691, β 1.720, γ 1.720 (I8)

Uranium silicate, hydrate - $5U_2O_3 \cdot 2SiO_2 \cdot 6H_2O$ (Nat. Soddyite) - 2848.92 - Greenish Yellow - Rhombic - D 4.63 (L18) - R.I. α 1.530, β 1.68, γ 1.710 (L18)

Uranium silicide - U_3Si - 742.27 - Triclinic - D 15.58 (X-ray)(Z22a)

Uranium silicide - U_3Si_2 - 770.33 - Triclinic - D 12.20 (X-ray)(Z22a)

Uranium silicide - USi - 266.13 - Rhombic - D 10.40 (X-ray) (Z22a)

Uranium silicide - α-USi_2 - 294.19 - Triclinic - D 8.98 (X-ray)(Z22a)

Uranium silicide - β-USi_2 - 294.19 - Hexagonal - D 9.25 (X-ray)(Z22a)

Uranium (IV) sulfate - $U(SO_4)_2$ - 430.20 - D 4.60 (B24)

Uranium (VI) sulfate, dioxy- - UO_2SO_4 - 366.14 - D 5.24^{18} (B24)
Uranium (VI) sulfate, dioxy-, hydrate - $UO_2SO_4 \cdot 3H_2O$ - 420.18 - Yellow - D 3.28 (I8) - D.T. 100 (I8)
Uranium (VI) sulfate, hydrate - $2UO_3 \cdot SO_3 \cdot H_2O$ (Nat. Zippeite) - 670.22 - Monoclinic - R.I. α 1.630, β 1.689, γ 1.739 (L12)
Uranium sulfide - U_4S_3 (Approx.) - 1048.48 - X-ray Lines 1.94, 1.66, 1.23 (A41)
Uranium (II) sulfide - US - 270.14 - Grayish - D 10.87 (X-ray) (E1) - M.P. > 2000 (E1)
Uranium (III) sulfide - U_2S_3 - 572.34 - Gray-Black - Needle - M.P. 1850 (E1)
Uranium (IV) sulfide - US_2 - 302.20 - Black - Rhombic - D 7.90 (X-ray) (E1) - M.P. 1850 (E1)
Uranium (IV) sulfide - US_2 - 302.20 - Iron Gray - Tetragonal - D 7.96^{25} (S107) - D.T. 1300 (In Vacuum) (P42)
Uranium (VI) sulfide - US_3 - 334.27 - Black - D 5.81^{25} (S107)
Uranium (IV) sulfide, oxy- - UOS - 286.14 - Black - Tetragonal - D 9.60 (X-ray) (E1)
Uranium (VI) vanadate, hydrate - $2UO_3 \cdot 3V_2O_5 \cdot 15H_2O$ (Nat. Uvanite) 1388.08 - Brownish Yellow - Rhombic - R.I. α 1.817, β 1.879, γ 2.057 (I8)

Vanadium - V - 50.95 - Gray - Cubic - D 6.0 (A20) - M.P. 1735 (A20) - B.P. 3400 (A20) - X-ray Lines 2.14, 1.236, 1.51 (A40)
Vanadium carbide - VC - 62.96 - Gray - D 5.4 (R12) - M.P. 2810 (R12) - B.P. 3900 (R12) - X-ray Lines 2.48, 2.15, 1.52 (A41)
Vanadium (II) chloride - VCl_2 - 121.86 - Apple Green - Hexagonal - D 3.23^{18} (I8)
Vanadium (III) chloride - VCl_3 - 157.32 - Peach Blossom - Tabular - D 3.00^{18} (I8)
Vanadium (IV) chloride - VCl_4 - 192.78 - Dark Reddish - Brown Liquid - Tetrahedral (L52) - D 1.816^{30} (I8) - M.P. -25.7 (S64) - B.P. 152 (S64)
Vanadium (V) chloride oxide - VCl_3O - 173.32 - Pale Yellow Liquid - D 1.829 (I8) - M.P. -79.5 (F31) - B.P. 127.2 (I8)
Vanadium (V) chloride oxide - V_2ClO_2 - 169.36 - D 3.64 (I8)
Vanadium (III) fluoride - VF_3 - 107.95 - Greenish Yellow - Rhombic - D 3.363^{19} (I8) - M.P. > 800 (M29)
Vanadium (IV) fluoride - VF_4 - 126.95 - Brownish Yellow - D 2.975^{23} (I8) - D.T. 325 (I8)
Vanadium (V) fluoride - VF_5 - 145.95 - Colorless - D 2.177^{19} (I8) - B.P. 111.2 (758 m.m.) (I8)
Vanadium (IV) fluoride oxide - VF_2O - 104.95 - Yellow - D 3.396^{19}(I8)
Vanadium (V) fluoride oxide - VF_3O - 123.95 - Yellowish White - D 2.459^{21} (I8) - M.P. 300 (I8) - B.P. 480 (I8)
Vanadium (II) oxide - VO - 66.95 - D 5.231^{25} (L12)
Vanadium (III) oxide - V_2O_3 - 149.90 - Black - D 4.87^{18} (I8) - M.P. 1970 (I8) - X-ray Lines 1.69, 2.70, 3.65 (A40)
Vanadium (IV) oxide - V_2O_4 - 165.90 - Dark Blue - D 4.654^{25} (L12) - M.P. 1637 (F61)
Vanadium oxide - $V_{12}O_{26}$ - 1027.40 - Monoclinic - D 3.9 (A3)

Vanadium (V) oxide - V_2O_5 - 181.90 - Reddish Yellow - Rhombic - D 3.357 (I8) - M.P. 656 (K79) - D.T. 1750 (M29) - R.I. α 1.46, β 1.52, γ 1.76 (Calc.)(K29) - X-ray Lines 4.38, 3.39, 2.87 (A40)
Vanadium (II) sulfide - VS - 83.02 - Brownish Black - Hexagonal - D 4.28 (B63) - X-ray Lines 2.04, 2.60, 1.67 (A41)
Vanadium (III) sulfide - V_2S_3 - 198.10 - Black - D 4.7 (I8) - D.T. > 660 (G21)
Vanadium (V) sulfide - V_2S_5 - 262.23 - Black - D 3.00 (I8) - -2S at 350-500 (G21)

Water - H_2O - 18.0160 - Colorless Liquid - D 1.0000000^4 (D30) - M.P. 0 or 273.16° K (A19) - B.P. 100.000 (K79) - R.I. 1.332502^{25} (Against air) (T38)
Water, heavy - HDO - 19.0228 - Colorless Liquid - M.P. 2.23 (Calc.) (G28) - B.P. 100.76 (R26)
Water, heavy - D_2O - 20.0294 - Colorless Liquid - D 0.99919^{25}(99.5%) (W50) - M.P. 3.82 (T13) - B.P. 101.42 (1 atm.) (L46) - R.I. 1.32844^{20} (L63)
Water, heavy - H_2O^{18} - 20.021 - Colorless Liquid - M.P. -0.1 (Calc.) (G28) - B.P. 100.13 (R26)

Wolfram - See Tungsten

Ytterbium - Yb - 173.04 - Hexagonal (A20) - D 7.03 (B94) - X-ray Lines 1.65, 1.93, 1.05 (A41)
Ytterbium carbonate, hydrate - $Yb_2(CO_3)_3 \cdot 4H_2O$ - 598.17 - D 3.67 (I8)
Ytterbium (II) chloride - $YbCl_2$ - 243.95 - Slight Reddish Yellow - Rhombic - D 5.08 (K52) - X-ray Lines 3.86, 2.40, 2.37 (A41)
Ytterbium chloride - $YbCl_3$ - 279.41 - D 3.781^{28} (H79) - M.P. 854(J19)
Ytterbium nitrate, hydrate - $Yb(NO_3)_3 \cdot 4H_2O$ - 431.13 - D 2.682 (I8)
Ytterbium oxalate - $Yb_2(C_2O_4)_3$ - 610.14 - D 2.439 (I8)
Ytterbium oxide - Yb_2O_3 - 394.08 - Colorless - D 9.17 (I8)
Ytterbium selenate - $Yb_2O_3 \cdot 3SeO_3$ - 774.96 - D 4.14 (I8)
Ytterbium selenate, hydrate - $Yb_2O_3 \cdot 3SeO_3 \cdot 8H_2O$ - 919.09 - Hexagonal - D 3.30 (I8)
Ytterbium selenide - Yb_2Se_3 - 582.96 - Violet Black - Cubic - D 7.33 (K48)
Ytterbium sulfate - $Yb_2(SO_4)_3$ - 634.28 - Colorless - D 3.793 (I8)
Ytterbium sulfate, hydrate - $Yb_2(SO_4)_3 \cdot 8H_2O$ - 778.41 - Prism - D 3.315^{20} (H53)
Ytterbium sulfide - Yb_2S_3 - 442.28 - Light Yellow - D 6.02^{25} (K49)

Yttrium - Y - 88.92 - Iron Gray - Hexagonal - D 5.51^{20} (A20) - M.P. 1490 (A20)(K79) - B.P. 4600 (A20) - X-ray Lines 2.79, 3.17, 3.06 (A41)
Yttrium aluminate - $Y_2O_3 \cdot Al_2O_3$ - Cubic - D 5.50 (X-ray) (F53)(S119)
Yttrium arsenate - $Y_2O_3 \cdot As_2O_5$ - 455.66 - Yellowish White - Tetragonal - D 4.56^{20} (S102) - X-ray Lines 3.38, 1.78, 1.44 (A41)
Yttrium chloride - YCl_3 - 195.29 - Colorless - D 2.81 (K37) - M.P. 721 (J16)

Yttrium columbate - $Y_2O_3 \cdot Cb_2O_5$ - 491.66 - Tetragonal - D 4.07 (X-ray) (M29) (S115)

Yttrium fluoride - YF_3 - 145.92 - Colorless - Cubic - D 4.01 (N37)

Yttrium fluoride - YF_3 - 145.92 - Colorless - Monoclinic - D 5.2 (N39)

Yttrium hydroxide - $Y(OH)_3$ - 139.94 - White-Yellow - Hexagonal - D 3.81 (X-ray) (F56)

Yttrium molybdate - $Y_2O_3 \cdot 3MoO_3$ - 657.69 - Colorless or Yellowish - Tetragonal - D 4.79^{18} (I8) - M.P. 1347 (I8) - R.I. ω -, ε 2.031 (5700 A)(W42)

Yttrium oxide - Y_2O_3 - 225.84 - Colorless - D 4.84^{15} (I8) - M.P. 2410 (I8) - B.P. 4300 (M88) - X-ray Lines 3.05, 1.87, 1.60 (A40)

Yttrium phosphate - $Y_2O_3 \cdot P_2O_5$ (Xenotime) - 367.80 - Tetragonal - D 3.78 (S102) - R.I. ω 1.721, ε 1.816 (I8) - X-ray Lines 1.75, 3.34, 1.42 (A41)

Yttrium phosphate - $2Y_2O_3 \cdot 3P_2O_5$ - 877.56 - D 3.059 (I8)

Yttrium phosphate, hydrate - $Y_2O_3 \cdot P_2O_5 \cdot 4H_2O$ (Nat. Weinschenkite) - 439.86 - D 3.263 (M54) - R.I. α 1.605, β 1.612, γ 1.645 (M54) - X-ray Lines 7.51, 4.18, 3.01 (M54)

Yttrium selenide - Y_2Se_3 - 414.72 - Gray Black - D $\sim$ 5.13 (K48)

Yttrium silicate - $Y_2O_3 \cdot SiO_2$ - 285.90 - Monoclinic (G34)

Yttrium silicate - $Y_2O_3 \cdot 2SiO_2$ - 345.96 - Monoclinic (G34)

Yttrium silicate, hydrate - $2Y_2O_3 \cdot 4SiO_2 \cdot H_2O$ (Nat. Thalenite) - 709.94 - Monoclinic - D 4.3 (L18) - R.I. α 1.731, β 1.738, γ 1.744 (I8)

Yttrium sulfate - $Y_2(SO_4)_3$ - 466.04 - Colorless - D 2.612 (I8) - D.T. 1020 (470 m.m.) (P13)

Yttrium sulfate, hydrate - $Y_2(SO_4)_3 \cdot 8H_2O$ - 610.17 - Colorless - Monoclinic - D 2.535^{20} (H53) - R.I. α 1.5433, β 1.5490, γ 1.5755 (I8)

Yttrium sulfide - Y_2S_3 - 274.04 - Yellow - D 3.82^{25} (K49) - M.P. 1930 (In Vacuum) (P46)

Yttrium tantalate - $Y_2O_3 \cdot Ta_2O_5$ - 667.60 - Tetragonal - D 5.74 (X-ray) (M29)(S119)

Yttrium vanadate - $Y_2O_3 \cdot V_2O_5$ - 407.74 - Tetragonal - D 4.49

Zinc - Zn - 65.38 - Bluish White - Hexagonal - D 7.133^{25} (A20) - M.P. 419.46 (A20) - T.P. 175, 320 (K79) - B.P. 906 (A20) - X-ray Lines 2.077, 1.339, 1.332 (A40)

Zinc aluminate - $ZnO \cdot Al_2O_3$ (Gahnite) - 183.32 - Colorless - Cubic - D 4.58^{11} (I8) - M.P. 1950 (B151) - R.I. 1.805 (G6) - X-ray Lines 2.44, 2.85, 1.431 (A40)

Zinc antimonate - $ZnO \cdot Sb_2O_5$ - 404.90 - White - Tetragonal - D 6.5 (C33)

Zinc antimonite - $ZnO \cdot Sb_2O_3$ - 372.90 - X-ray Lines 3.29, 2.56, 1.720 (A40)

Zinc arsenate, pyro- - $2ZnO \cdot As_2O_5$ - 392.58 - D 4.701^{21} (I8) - X-ray Lines 3.11, 2.57, 1.629 (A40)

Zinc arsenate, ortho- - $3ZnO \cdot As_2O_5$ - 473.96 - White - Rhombic - D 4.913^{15} (I8)

Zinc arsenate, hydrate - $3ZnO \cdot As_2O_5 \cdot 8H_2O$ (Nat. Koettigite) - 618.09 - Monoclinic - D 3.309^{15} (I8) - D.T. 100 (I8) - R.I. α 1.662, β 1.683, γ 1.717 (I8) - X-ray Lines 3.25, 7.9, 2.79 (A40)

Zinc arsenate, hydrate - $4ZnO \cdot As_2O_5 \cdot H_2O$ (Nat. Adamite) - 573.36 - Colorless - Rhombic - D 4.345 (I8) - M.P. > 100 (I8) - R.I. α 1.708 β 1.733, γ 1.758 (I8) - X-ray Lines 2.45, 2.99, 2.68 (A40)

Zinc arsenite - $ZnO \cdot As_2O_3$ - 279.20 - X-ray Lines 3.15, 2.95, 2.18 (A40)

Zinc arsenite - $3ZnO \cdot As_2O_3$ ('A') - 441.96 - X-ray Lines 4.00, 2.62, 3.19 (A40)

Zinc arsenite - $3ZnO \cdot As_2O_3$ ('B') - 441.96 - X-ray Lines 2.88, 3.25, 2.47 (A40)

Zinc borate - $ZnO \cdot B_2O_3$ - 151.02 - Colorless - M.P. 1000 (I6)

Zinc borate - $3ZnO \cdot 2B_2O_3$ - 383.42 - Colorless - M.P. 980 (P8)

Zinc borate - $3ZnO \cdot 2B_2O_3$ - Glass - 383.42 - Colorless - D 3.64 (P8)

Zinc borate - $5ZnO \cdot 2B_2O_3$ - 546.18 - Colorless - M.P. 1080 (Incong.) (I6) - R.I. α 1.673, β 1.742, γ 1.747 (I6)

Zinc borate, fluo- - $ZnF_2 \cdot 2BF_3$ - 239.02 - Colorless - R.I. α -, β >1.36 $\gamma=\alpha+0.011$ (D19)

Zinc carbonate - $ZnCO_3$ (Smithsonite) - 125.39 - Colorless - Trigonal - D 4.3476^{25} (A26) - D.T. 296 (1 atm. CO_2)(K79) - R.I. ω 1.849, ε 1.621 (M89) - X-ray Lines 2.73, 1.698, 3.54 (A40)

Zinc carbonate, basic- - $2ZnCO_3 \cdot 3Zn(OH)_2$ (Nat. Hydrozincite) - 548.97 - Monoclinic (?) - D 3.7 (I8) - R.I. α 1.640, β 1.736, γ 1.750 (I8)

Zinc chloride - $ZnCl_2$ - 136.29 - Colorless - Cubic - D 2.925^{25} (K54) - M.P. 283 (K15) - B.P. 732 (I8) - R.I. ω 1.687, ε 1.713 (W42) - X-ray Lines 4.8, 3.05, 1.86 (A41)

Zinc chloride fluoride - $ZnF_2 \cdot ZnCl_2$ - 239.67 - Colorless - Biaxial - M.P. 689 (M78) - R.I. 1.70 (Mean) (M78)

Zinc chromate $ZnO \cdot CrO_3$ - 181.39 - Lemon Yellow - Rhombic - D 4.22 (X-ray)(B119)(S119)

Zinc chromite - $ZnO \cdot Cr_2O_3$ - 233.40 - Cubic - D 5.29 (P15) - X-ray Lines 2.50, 1.465, 1.597 (A40)

Zinc chromite, thio- - $ZnS \cdot Cr_2S_3$ - 297.66 - Cubic - D 4.05 (X-ray) (N10)

Zinc cobalt (III) oxide - $ZnO \cdot Co_2O_3$ - 247.26 - Cubic - D 5.94 (X-ray) (H88) - X-ray Lines 2.43, 2.84, 1.55 (A40)

Zinc columbate - $ZnO \cdot Cb_2O_5$ - 347.20 Brown - Rhombic - D 5.69^{17}(M29

Zinc ferrite - $ZnO \cdot Fe_2O_3$ - 241.08 - Brownish Red - Cubic - D 5.290 (P55) - M.P. 1590 (A34) - R.I. 2.31 (Li-Line)(P55) - X-ray Lines 2.53, 1.49, 1.62 (A40)

Zinc ferrite - $2ZnO \cdot 3Fe_2O_3$ - 641.86 - D 5.189 (H65)

Zinc fluoride - ZnF_2 - 103.38 - Colorless - Monoclinic, Biaxial - D 4.858^{25} (B69) - M.P. 872 (I8) - B.P. 1500 (R71) - R.I. ω 1.510, ε 1.526 (M78) - X-ray Lines 3.33, 2.60, 1.75 (A40)

Zinc fluoride, hydrate - $ZnF_2 \cdot 4H_2O$ - 175.44 - X-ray Lines 4.89, 4.12, 2.99 (A40)

Zinc formate - $Zn(HCO_2)_2$ - 155.42 - Colorless - D 2.268 (A36)

Zinc gallate - $ZnO \cdot Ga_2O_3$ - 268.82 - White - Cubic - D 6.154 (X-ray) (B159) - R.I. > 1.74 (B159)

Zinc germanate - $2ZnO\cdot GeO_2$ - 267.36 - D 4.823 (X-ray)(S20) - M.P. 1490 (I6) - R.I. ε 1.802 (I6)

Zinc hydroxide - $Zn(OH)_2$ (Stable) - 99.40 - Colorless - Rhombic - D 3.084^{21} (F55) - D.T. 125 (I8) - X-ray Lines 4.38, 3.27, 2.71 (Form not defined)(A40)

Zinc hydroxide - $Zn(OH)_2$ (Unstable) - 99.40 - Colorless - Needle - D 2.882^{18} (F55)

Zinc lead antimonate - $ZnO\cdot 2PbO\cdot Sb_2O_5$ - 851.32 - Orange Yellow - Anisotropic - D 7.6 (S112)

Zinc lead silicate - $ZnO\cdot PbO\cdot SiO_2$ (Nat. Larsenite) - 364.65 - Rhombic - R.I. α 1.92, β 1.95, γ 1.96 (P6)

Zinc manganese (II) fluoride - $ZnF_2\cdot MnF_2$ - 196.31 - Uniaxial - M.P. 897 (M78) - R.I. ω 1.487, ε 1.517 (M78)

Zinc molybdate - $ZnO\cdot MoO_3$ - 225.33 - Colorless with Yellowish Tint - Tetragonal - M.P. 900 (G41)

Zinc nitrate - $Zn(NO_3)_2$ - 251.40 - D.T. 302 (1 atm.) (K79)

Zinc nitrate, hydrate - $Zn(NO_3)_2\cdot H_2O$ - 207.41 - Colorless - M.P. 70.7 (E27)

Zinc nitrate, hydrate - $Zn(NO_3)_2\cdot 2H_2O$ - 225.43 - Colorless - M.P.55.4 (E27)

Zinc nitrate, hydrate - $Zn(NO_3)_2\cdot 3H_2O$ (?) (E27) - 243.44 - Colorless - M.P. 44.07 (I8)

Zinc nitrate, hydrate - $Zn(NO_3)_2\cdot 4H_2O$ - 261.46 - Colorless - M.P.44.7 (E27)

Zinc nitrate, hydrate - $Zn(NO_3)_2\cdot 6H_2O$ - 297.49 - Colorless - Tetragonal - D 2.065^{14} (I8) - M.P. 36.1 (E27)

Zinc oxalate - ZnC_2O_4 - 153.40 - Colorless - D 3.28^{25} (H93)

Zinc oxide - ZnO (Zincite) - 81.38 - Colorless - Hexagonal - D 5.664^{18} (R52) - M.P. 1975 (B149) - T.P. 570 (L24) - D.T. 1950 (1 atm.) (P67) - R.I. ω 2.004, ε 2.020 (W42) - X-ray Lines 2.46, 2.81, 2.61 (A40)

Zinc oxide, per - ZnO_2 - 97.38 - Whitish Yellow - D 1.571 (R12) - X-ray Lines 2.43, 2.81, 1.467 (A40)

Zinc oxide, per-, hydrate - $2ZnO_2\cdot H_2O$ - 212.78 - Cream White - D 3 (C43)

Zinc phosphate, pyro- - $2ZnO\cdot P_2O_5$ - 304.72 - Colorless - D 3.755^{23} (C38) - X-ray Lines 3.03, 2.12, 2.56 (A40)

Zinc phosphate, ortho- - $3ZnO\cdot P_2O_5$ - 386.10 - Colorless - Rhombic - D 3.998^{15} (I8) - M.P. 900 (I8) - X-ray Lines 3.60, 3.07, 3.99(A40)

Zinc phosphate - $4ZnO\cdot P_2O_5$ - 467.48 - Colorless - Rhombic (?) - R.I. α 1.630, β 1.656, γ 1.660 (W42)

Zinc phosphate, hydrate - $ZnO\cdot P_2O_5\cdot 4H_2O$ - 295.40 - Colorless - Trigonal - D.T. 100 (I8)

Zinc phosphate, hydrate - $2ZnO\cdot P_2O_5\cdot 5H_2O$ - 394.80 - Colorless - X-ray Lines 3.75, 5.22, 4.55 (A40)

Zinc phosphate, hydrate - $3ZnO\cdot P_2O_5\cdot 2H_2O$ - 422.13 - Colorless - X-ray Lines 1.810, 2.93, 3.19 (A40)

Zinc phosphate, hydrate - $3ZnO\cdot P_2O_5\cdot 4H_2O$ (I) (Nat. Hopeite) - 458.16 - Rhombic - D 3.04 (I8) - T.P. > 105 (I8) - R.I. α 1.572, β 1.591, γ 1.59 (I8) - X-ray Lines 2.84, 4.58, 1.933 (Form not defined) (A40)

Zinc phosphate, hydrate - $3ZnO\cdot P_2O_5\cdot 4H_2O$ (II)(Nat. Hopeite) - 458.16 - Rhombic - D 3.03 (I8) - T.P. > 140 (I8) - R.I. α 1.574, β 1.582, γ 1.637 (I8)

Zinc phosphate, hydrate - $3ZnO\cdot P_2O_5\cdot 4H_2O$ (Nat. Parahopeite) - 458.16 - Triclinic - T.P. > 163 (I8) - R.I. α 1.614, β 1.625, γ 1.637 (I8)

Zinc phosphate, hydrate - $3ZnO\cdot P_2O_5\cdot 8H_2O$ - 530.23 - D 3.109^{15} (S25)

Zinc phosphate, hydrate - $4ZnO\cdot P_2O_5\cdot H_2O$ - 485.50 - Colorless - Rhombic - R.I. α 1.608, β 1.624, γ 1.629 (W42)

Zinc phosphate, hydrate - $4ZnO\cdot P_2O_5\cdot H_2O$ (Nat. Tarbuttite) - 485.50 - Triclinic - D 4.13 (I8) - R.I. α 1.660, β 1.705, γ 1.713 (I8)

Zinc phosphate, hydrate - $4ZnO\cdot P_2O_5\cdot 4H_2O$ (Nat. Spencerite) - 539.54 - Monoclinic - D 3.14 (I8) - D.T. 100 (I8) - R.I. α 1.586, β 1.602, γ 1.608 (I8)

Zinc selenate, hydrate - $ZnSeO_4\cdot 5H_2O$ - 298.42 - Trigonal - D 2.591 (I8) - D.T. > 50 (I8)

Zinc selenate, hydrate - $ZnSeO_4\cdot 6H_2O$ - 316.44 - Tetragonal - D 2.325 (I8) - R.I. ω 1.5291, ε 1.5039 (I8)

Zinc selenide - ZnSe - 144.34 - Yellowish Red - Cubic, Hexagonal - D 5.42^{18} (I8) - M.P. >1100 (C26) - R.I. 2.89 (I8) - X-ray Lines 3.28, 1.995, 1.701 (A40)

Zinc silicate - $ZnO\cdot SiO_2$ (Not found by Bunting, (B149)) - 141.44 - Colorless - Hexagonal, Rhombic (?) - D 3.52 (I8) - M.P. 1437 (Incong.?) (I8) - R.I. α 1.616, β -, γ 1.623 (J7)

Zinc silicate - $ZnO\cdot SiO_2$ (Glass) - 141.44 - Colorless - D 3.86 (S95) - R.I. 1.650 (J9)

Zinc silicate - $2ZnO\cdot SiO_2$ (Willemite) - 222.82 - Colorless - Tetragonal, Hexagonal - D 4.103^{28} (B67) - M.P. 1512 (B149) - R.I. ω 1.692, ε 1.720 (B149) - X-ray Lines 1.42, 2.63, 2.31 (A41)

Zinc silicate - $2ZnO\cdot SiO_2$ (Glass) - 222.82 - Colorless - D 3.850 (B73)

Zinc silicate - α-$2ZnO\cdot SiO_2$ - 222.82 - Colorless - R.I. ω 1.695, ε 1.715 (I6)

Zinc silicate - β-$2ZnO\cdot SiO_2$ - 222.82 - Colorless - R.I. 1.700 (I6)

Zinc silicate - γ-$2ZnO\cdot SiO_2$ - 222.82 - Colorless - R.I. α 1.685, β 1.700, γ 1.703 (I6)

Zinc silicate, fluo- - $ZnF_2\cdot SiF_4$ - 207.44 - Colorless - X-ray Lines 4.72, 4.17, 2.59 (A40)

Zinc silicate, fluo-, hydrate - $ZnSiF_6\cdot 6H_2O$ - 315.54 - Colorless - Hexagonal - D 2.12 (H2) - R.I. ω 1.3824, ε 1.3956 (G41)

Zinc silicate, hydrate - $2ZnO\cdot SiO_2\cdot H_2O$ (Nat. Hemimorphite) - 240.84 - Trigonal, Rhombic - D 3.45 (I8) - R.I. α 1.614, β 1.617, γ 1.636 (I8) - X-ray Lines 3.12, 6.7, 3.29 (A41)

Zinc sulfate - $ZnSO_4$ (Zincosite) - 161.45 - Colorless - Rhombic - D 3.74 (I8) - T.P. 740 (F62) - D.T. 740 (1 atm.) (K79) - R.I. α 1.658, β 1.669, γ 1.670 (I8) - X-ray Lines 2.64, 4.21, 3.59 (A40)

Zinc sulfate, hydrate - $ZnSO_4\cdot H_2O$ - 179.46 - D 3.195^{28} (S56) - D.T. 238 (I8) - X-ray Lines 3.40, 4.80, 3.06 (A40)

Zinc sulfate, hydrate - $ZnSO_4\cdot 6H_2O$ - 269.54 - Colorless - Monoclinic (Tetragonal) - D 2.072^{18} (I8) - $-5H_2O$ at 60 (C53) - X-ray Lines 4.40, 4.05, 2.92 (A40)

Zinc sulfate, hydrate - $ZnSO_4 \cdot 7H_2O$ - 287.56 - Colorless - Monoclinic - R.I. α 1.4567, β 1.4800, γ 1.4840 (P54)
Zinc sulfate, hydrate - $ZnSO_4 \cdot 7H_2O$ (Goslarite) - 287.56 - Colorless - Rhombic - D 1.957^{25} (S56) - T.P. 39 (I8) - D.T. 280 (I8) - R.I. α 1.4620, β 1.4860, γ 1.4897 (I8) - X-ray Lines 4.20, 5.3, 3.44 (Form not defined) (A40)
Zinc sulfide - ZnS (I)(Wurtzile) - 97.45 - Hexagonal - D 4.087 (I8) - M.P. 1645 (Under Pressure) (K15) - S.P. 1185 (I8) - R.I. ω 2.356, ε 2.378 (I8) - X-ray Lines 1.91, 1.76, 3.30 (A41)
Zinc sulfide - ZnS (II)(Sphalerite) - 97.45 - Cubic - D 4.102^{25} (I8) Transition to I 1020 (I8) - R.I. 2.3682 (I8) - X-ray Lines 3.12, 1.91, 1.63 (A40)(A41)
Zinc telluride - ZnTe - 192.99 - Red - Cubic - D 5.54^{19} (I8) - M.P. 1240 (K79) - R.I. 3.56 (I8) - X-ray Lines 3.49, 2.14, 1.823 (A40)
Zinc tin (IV) oxide - $2ZnO \cdot SnO_2$ - 313.46 - Colorless - Cubic - D 6.39 (X-ray) (T14) - X-ray Lines 2.61, 1.66, 1.53 (A41)
Zinc titanate - $ZnO \cdot TiO_2$ - 161.28 - Pale Violet - Needle - D 3.17^{20} (I8)
Zinc titanate - $ZnO \cdot 3TiO_2$ - 321.08 - Violet - D 4.92^{15} (I8)
Zinc titanate - $2ZnO \cdot TiO_2$ - 242.66 - Black - D 5.12 (C50) - X-ray Lines 2.54, 1.49, 1.62 (A41)
Zinc titanate - $3ZnO \cdot 2TiO_2$ - 403.94 - Yellow - D 3.83 (I8)
Zinc titanate - $4ZnO \cdot 5TiO_2$ - 725.02 - Pale Brown - Small Leaflets - D 3.68^{19} (I8)
Zinc tungstate - $ZnO \cdot WO_3$ - 313.30 - Colorless - Monoclinic - D 7.79 (X-ray)(G41)

Zirconium - Zr - 91.22 - Silvery Gray - Hexagonal - D 6.5^{20} (A20) - M.P. 1750 (K79)(A20) - T.P. 862 (K79)(A20) - B.P. 5050 (A20) - X-ray Lines 2.81, 1.84, 2.60 (A41)
Zirconium arsenate - $ZrO_2 \cdot As_2O_5$ - 353.04 - Transition to $2ZrO_2 \cdot As_2O_5$ 900 (P39)
Zirconium arsenate - $2ZrO_2 \cdot As_2O_5$ - 476.26 - Transition to $3ZrO_2 \cdot As_2O_5$ 950 (P39)
Zirconium arsenate - $3ZrO_2 \cdot As_2O_5$ - 599.48 - Transition to ZrO_2 1000 (P39)
Zirconium carbide - ZrC - 103.23 - Gray, Metallic - M.P. 3532 (R12) - B.P. 5100 (R12) - X-ray Lines 2.75, 2.38, 1.68 (A41)
Zirconium chloride - $ZrCl_4$ - 233.05 - Colorless - D 2.803 (V7) - M.P. 437 (25 atm.) (R1) - S.P. 331 (R1)
Zirconium columbate - $ZrO_2 \cdot 5Cb_2O_5$ - 1452.32 - Acicular - D 5.14^{17}(M29)
Zirconium fluoride - ZrF_4 - 167.22 - Colorless - Monoclinic - D 4.54^{25}(H55) - B.P. Red Heat (R68) - R.I. α 1.57, β 1.60, γ - (H55)
Zirconium nitrate - $Zr(NO_3)_4$ - 339.25 - Colorless - R.I. ω 1.60, ε 1.61 (T2)
Zirconium nitrate, hydrate - $Zr(NO_3)_4 \cdot 5H_2O$ - 429.33 - Colorless - X-ray Lines 9.6, 6.9, 4.73 (A40)
Zirconium oxide - ZrO_2 (I) - 123.22 - Rhombic, Cubic, Trigonal - D 6.27 (X-ray)(P17) - M.P. 2715 (Z37) - Undercooled T.P. 625 (C47) - X-ray Lines 3.19, 2.85, 1.81 (Form not defined) (A40)

Zirconium oxide - ZrO_2 (II) - 123.22 - Tetragonal - D 6.10 (C47) - Transition to I 1900 (C47)

Zirconium oxide - ZrO_2 (III) (Baddeleyite) - 123.22 - Slight Yellow or Colorless - Monoclinic - D 5.56 (C47) - Transition to II 1000 (C47) - M.P. 2690 (K79) - T.P. 625, 1000, 1900 (K79) - R.I. α 2.13 β 2.19, γ 2.20 (I8)

Zirconium phosphate - $ZrO_2 \cdot P_2O_5$ - 265.18 - Cubic - D 3.195 (L44)

Zirconium silicate - $ZrO_2 \cdot SiO_2$ (Zircon) - 183.28 - Colorless - Tetragonal and two other modifications - D 4.15, 4.32, 4.7 (C28) - M.P. 2430 (Z38) - R.I. ω 1.923-1.960, ϵ 1.966-2.015 (I8) - X-ray Lines 3.21, 1.70, 1.37 (A41)

Zirconium silicate - $ZrO_2 \cdot SiO_2$ (Glass) - 183.28 - Colorless - R.I. $\sim$ 1.46 (Z38)

Zirconium sulfate - $Zr(SO_4)_2$ - 283.35 - Colorless - D 3.22^{18} (B24)

Zirconium sulfide - ZrS_2 - 155.35 - Cinnamon-Brown - Hexagonal - D 3.87 (P44) - M.P. (Syn.) $\sim$ 1550 (V12)

Zirconium sulfide oxide - ZrSO - 139.29 - Light Yellow - Cubic (M18) - D 4.87 (I8)

Zirconium vanadate - $ZrO_2 \cdot V_2O_5$ - 305.12 - D.T. 670 (P39)

A 1. Abegg, R., Auerbach, F., and Koppel, I., Handbuch der Anorganischen Chemie, 4 volumes, 1905-
A 2. Achenbach, H., Chem. Erde, 6, 319 (1931)
A 3. Aebi, F., Helv. Chim. Acta 31, 8-21 (1948) (in German)
A 4. Agafonova, T.N. and Iskyul, E.V., Compt. rend. acad. sci., U.R.S.S., 22, 325-6 (1939)
A 5. Ahlfeld, F., and Mosebach, R., Centr. Mineral. Geol., 1936 A, 226-31, 287
A 6. Aiken, J.K., Haley, J.B., and Terrey, H., Trans. Faraday Soc., 32, 1617-22 (1936)
A 7. Alexander, L.T., Faust, G.T., Hendricks, S.B., Insley, H., and McMurdie, H.F., Am. Mineral. 28, 1 (1943)
A 8. Alimarin, I.P., Zavodskaya Lab. 9, 915-16 (1940); Khim. Refer. Zhur. 4, No. 3, 82-3 (1941)
A 9. Allen, E.T., Grenshaw, J.L., and Merwin, H.E., Am. J. Sci.,(4) 34, 341-96 (1912)
A10. Allen, E.T., Grenshaw, J.L., Johnston, J., and Larsen, E.S., Am. J. Sci., (4), 33, 169-236 (1912)
A11. Allen, E.T., and White, W.P., Am. J. Sci., (4), 27, 1-46 (1909)
A12. Allen, E.T., Wright, F.E., and Clement, J.K., Am. J. Sci., (4), 22, 401 (1906)
A13. Allen, V.T., Fahey, J.J. and Axelrod, J.M., Am. Mineral. 33, 122-34 (1948)
A14. Alterthum, H., and Koref, F., Z. Elektrochem., 31, 508-511 (1925)
A15. Amadori, M., Atti. Istit. Veneto, 72, II, 896 (1912/1913)
A16. Amadori, M., Atti. Istit. Veneto, (8), 17, II, 1665 (1913/1914)
A17. Amadori, M., Atti. accad. Lincei, 27, I, 143-8 (1918)
A18. American Chemical Society, J.A.C.S., Nov. 1948
A19. American Institute of Physics, Temperature, Its Measurement and Control in Science and Industry, Reinhold Publishing Corp., New York, N.Y. 1941
A20. American Society for Metals, Metals Handbook, 1948 Edition
A21. Aminoff, G., Geol. För. Förh., 45, 124-43 (1923)
A22. Aminoff, G., Z. Krist., 60, 262-74 (1924)
A23. Anderson, C.T., J.A.C.S., 53, 476-83 (1931)
A24. Anderson, C.T., J.A.C.S., 54, 107-11 (1932)
A25. Anderson, C.T., J.A.C.S., 56, 340-2 (1934)
A26. Anderson, C.T., J.A.C.S., 56, 849-51 (1934)
A27. Anderson, H.H., J.A.C.S., 66, 934-5 (1944)
A28. Anderson, H.H., J.A.C.S., 67, 859 (1945)
A29. Anderson, J.S., J. Chem. Soc. 1943, 141-3
A30. Andersen, O., J. Washington Acad., 4, 318-25 1914)
A31. Andreae, J.L., Z. phys. Chem., 76, 491-6 (1911)
A32. Angel, F., Z. Kryst., 72, 1-41 (1929)
A33. Argon, P.A., A.E.C.D. 1878
A34. Arkel, A.E.v., Verwey, E.J.W. and Bruggen, M.G.v., Rec. trav. chim. 55, 331-9 (1936)
A35. Aruja, E., Mineral. Mag. 27, 65-74 (1945)
A36. Ashton, F.W., Houston, D.F. and Saylor, C.P., Bur. Stand. J. Res., 11, 233-53 (1933)

A37. Ashton, F.W., and Wilson, R., Am. J. Sci., (5), 13, 209-18 (1927)
A38. Askenasy, P. and Nessler, F., Z. anorg. allgem. Chem., 189, 305-28 (1930)
A39. Assarsson, G., Z. anorg. allgem. Chem., 200, 385-408 (1931)
A40. A.S.T.M., X-ray Diffraction Patterns, Original Set, June, 1945
A41. A.S.T.M., X-ray Diffraction Patterns, First Supplement, August, 1945
A42. Atanasin, I.A., and Babor, M., Chem. Abs., 34, 2271 (1940)
A43. Athavale, V.T., and Jatkar, S.K.K., J. Indian Inst. Sci., 20A, Pt. 8, 55-66 (1937)
A44. Atomic Weights, 1948, J.A.C.S., November, 1948.
A45. Aurivillius, B. and Sillen, L.G., Nature 155, 305 (1945)
A45a Aurousseau, M., and Merwin, H.E., Am. Mineral. 13, 563 (1928)
A46. Austin, A.E., J. Am. Ceram. Soc. 30, 218-20 (1947)
A47. Austin, J.B. and R.H.H. Pierce, Jr., J. Chem. Phys., 3, 683-6 (1935)
A48. Auwers O.v., Naturwissenschaften, 19, 133-4 (1931)

B 1. Baccaredda, M., Gazz. chim. ital., 66, 539-43 (1936)
B 2. Bailly, R., Ann. soc. geol. Belg. Bull. 65, B 169-71 (1942); Chem. Zentr. 1942, II, 2123-4
B 3. Bainbridge, K.T., Phys. Rev., 44, 57 (1933)
B 4. Baker, C.L., and Jue, L.R., J. Phys. Chem., 42, 165-9 (1938)
B 5. Baker, C.L., Woodward, H.T., and Pabst. A., Am. Mineral., 18, 206-15 (1933)
B 6. Bale, W.F., Bonner, J.F., Hodge, H.C., Adler, H., Wreath, A.R. and Bell, R., Ind. Eng. Chem. Analy. Ed., 17, 491 (1945)
B 7. Ballo, R., and Dittler, E., Z. anorg. allgem. Chem., 76, 39-69 (1912)
B 8. Bannister, F.A., Mineral. Mag., 23, 587-97 (1934)
B 9. Bannister, F.A., Mineral. Mag., 24, 49-58 (1935)
B10. Barblan, F.F., Schweiz. Mineialog. Petrog. Mitt., 23, 295 (1943)
B11. Barlett, H.B., J. Am. Ceram. Soc., 15, 361-4 (1932)
B12. Baroni, A., Gazz. Chim. Ital., 70, 478-83 (1940)
B13. Barrett, R.L. and McCaughey, W.J., Am. Mineral., 27, 680 (1942)
B14. Barth, T.F.W., Am. J. Sci., (5), 19, 135-46 (1930)
B15. Barth, T., and Berman, H., Chem. Erde, 5, 22-42 (1930)
B16. Bartlett, G., and Langmiur, I., J.A.C.S., 43, 84-91 (1921)
B17. Baumgarten, P., and Thilo, E., Ber., 71, 2596-2603 (1938)
B18. Baur, E., and Brunner, R., Z. Elektrochem., 40, 154-8 (1934)
B19. Baxter, G.P., and Tilley, G.S., J.A.C.S., 31, 201-21 (1909)
B20. Baxter, G.P., and Tuemmler, F.D., J.A.C.S., 60, 602-4 (1938)
B21. Bazilevich, A., Mineral. Suire, 9, (9), 25-30 (1934)
B22. Beamer, W.H. and Maxwell, C.R., J. Chem. Phys. 14, 569 (1946)
B23. Beck, G., Z. anorg. allgem. Chem., 156, 288-300 (1926) Footnote.
B24. Beck, G., Z. anorg. allgem. Chem., 174, 31-41 (1928)
B25. Beck, G., Z. anorg. allgem. Chem., 206, 416-24 (1932)
B26. Beck, G., and Nowacki, W., Naturwissenschaften, 26, 495-6 (1938)
B27. Beck, W.R., J. Am. Ceram. Soc., 32, 147 (1949)
B28. Becker, K., and Jancke, W., Z. phys. chem., 99, 267-74 (1921)

B29. Behr, Neues Jahrb. Miner. Geol., 1, 138 (1903)
B30. Beintema, J., Z. Krist. (A) 97, 300-322 (1937)
B31. Belladen, L., Gazz. chim. ital., 52 II, 160-4 (1922)
B32. Belyankin, D.S., Compt. rend. acad. sci. U.R.S.S. 42, 304 (1944)
B33. Benrath, A., and Thiemann, W., Z. anorg. allgem. chem., 217, 347-52 (1934)
B34. Benrath, A., and Thoennessen, C., Z. anorg. allgem. chem., 203, 405-16 (1931)
B35. Berezknor, A.S., Compt. rend. acad. sci. U.R.S.S. 53, 47 (1946)
B36. Bergman, A. G. and Dergunov, E.F., Compt. rend. acad. sci., U.R.S.S., 31, 753, 755, (1941)
B37. Bergman, A.G. and Parlenko, Compt. rend. acad. sci., U.R.S.S. 31, 818-19 (1941)
B38. Bergmann, A., Z. anorg. allgem. chem., 231, 269-80 (1937)
B39. Bernal, J.D., Dyatlova, E., Kasarnovskii, I., Raikhstein, S.I., and Ward, A.G., Z. Krist., 92, 344-54 (1935)
B40. Berry, L.G., Univ. Toronto Studies, Geol. Ser. No. 44, 5-19 (1940)
B41. Berthoud, A., Helv. chim. acta, 5, 513-43 (1922)
B41a Bethe, H.A., Elementary Nuclear Theory, John Wiley & Sons, New York, 1947
B42. Bijvoet, J.M. and Levy, J.A., Rev. trav. chim., 59, 908-12 (1940)
B43. Billiet, I.V. and deJong, W.F., Naturiv. Tijdschr. 18, 261-5 (1936)
B44. Biltz. W., Z. anorg. allgem. chem., 59, 272-84 (1908)
B45. Biltz, W., Z. anorg. allgem. chem., 159, 96-102 (1926)
B46. Biltz, W., Z. anorg. allgem. chem., 170, 161-83 (1928)
B47. Biltz, W., Z. anorg. allgem. chem., 193, 321-50 (1930)
B48. Biltz, W., Z. anorg. allgem. chem., 214, 225-38 (1933)
B49. Biltz, W., Z. anorg. allgem. chem., 220, 312-6 (1934)
B50. Biltz, W., Z. anorg. allgem. chem., 233, 282-5 (1937)
B51. Biltz, W., and Balz, G., Z. anorg. allgem. chem., 170, 327-41 (1928)
B52. Biltz, W., and Birk, E., Z. anorg. allgem. chem., 127, 34-42 (1923)
B53. Biltz, W., and Birk, E., Z. anorg. allgem. chem., 134, 125-36 (1924)
B54. Biltz, W., and Boucher, L. Le, Anal. soc. espan. fis. quim., 31, I 428 (1933)
B55. Biltz, W., Ehrlich, P., and Meisel, K., Z. anorg. allgem. chem., 234, 97-116 (1937)
B56. Biltz, W., and Fendius, C., Z. anorg. allgem. chem., 172, 385-94 (1928)
B57. Biltz, W., and Fischer, W., Z. anorg. allgem. chem., 166, 290-8 (1927)
B58. Biltz, W., and Huelsmann, O., Z. anorg. allgem. chem., 207, 377-84 (1932)
B59. Biltz, W., and Jeep, K., Z. anorg. allgem. chem., 162, 32-48 (1927)
B60. Biltz, W., and Juza, R., Z. anorg. allgem. chem., 190, 161-77 (1930)

B61. Biltz, W., and Keunecke, E., Z. anorg. allgem. chem., 147, 171-87 (1925)

B62. Biltz, W., and Koecher, A., Z. anorg. allgem. chem., 238, 81-93 (1938)

B63. Biltz, W., and Koecher, A., Z. anorg. allgem. chem., 241, 324-37 (1939)

B64. Biltz, W., and Laar, J., Z. anorg. allgem. chem., 228, 257-67 (1936)

B65. Biltz, W., and Lemke, A., Z. anorg. allgem. chem., 186, 373-86 (1930)

B66. Biltz, W., and Lemke, A., Z. anorg. allgem. chem., 203, 321-9 (1931)

B67. Biltz, W., and Lemke, A., Z. anorg. allgem. chem., 203, 330-44 (1931)

B68. Biltz, W., and Mueller, H., Z. anorg. allgem. chem., 163, 257-96 (1927)

B69. Biltz, W., and Rahlfs, E., Z. anorg. allgem. chem., 166, 351-76 (1927)

B70. Biltz, W., Sapper, A., and Wuennenberg, E., Z. anorg. allgem. chem., 203, 277-306 (1931)

B71. Biltz, W., Voight, A., and Meisel, K., Z. anorg. allgem. chem., 228, 275-96 (1936)

B72. Biltz, W., and Weibke, F., Z. anorg. allgem. chem., 203, 3-8 (1931)

B73. Biltz, W., and Weibke, F., Z. anorg. allgem. chem., 203, 345-64 (1931)

B74. Biltz, W., and Wiechmann, F., Z. anorg. allgem. chem., 228, 268-74 (1936)

B75. Biltz, W., and Wilke-Dorfurt, E., Z. anorg. allgem., 48, 297-318 (1906)

B76. Binder, O., Compt. rend., 201, 1035-6 (1935)

B77. Birckenbach, L., and Huttner, K., Z. anorg. allgem. chem., 190, 1-26 (1930)

B78. Birk, E., and Biltz, W., Z. anorg. allgem. chem., 153, 115-25 (1926)

B79. Blasdale, W.C., and Slansky, C.M., J.A.C.S., 61, 917-20 (1939)

B80. Boeke, H.E., Centr. Miner. Geol., 1910, 533

B81. Boeke, H.E., Neues Jahrb. Min., I, 91 (1912)

B82. Boeke, H.E., Mitt. Natf. Ges. Halle a.S. 3, (1913)

B83. Boer, J.H. de, and Liempt, J.A.M. van, Rec. Trav. Chim. Pays. Bas., 46, 124 (1927)

B84. Bøggild, O.B., Medd. om Grønland, 92, (9), 12 pp. (1933)

B85. Bøggild, O.B., Norsk. Geol. Tids. 26, 192-8 (1947) (in Danish)

B86. Bogue, R.H., J.Res. Natl. Bur. Stand. 39, 177-90 (1947)

B87. Boguslavskaya, B.E., J. Gen. Chem., (U.S.S.R.), 9, 1077-85 (1939)

B88. Bøgvad, R., Medd. om. Grønland, 92, (8), 11 pp. (1933)

B89. Bøgvad, R., Medd. om. Grønland, 119, No. 7, 11 pp. (1938)

B90. Boldyreva, A.M., Mat. wiss. Zentralinst. geol. Erforsch, 1, 62-5 (1936)

B91. Bolland, A., Monatsh. Chem., 31, 387-420 (1910)

B92. Bolland, A., Sitzungsb. Kais. Akad. Wiss., Wien, 119, IIb, 279 (1910)

B 93. Bommer, H., Z. anorg. allgem. chem., 242, 277-80 (1939)

B 94. Bommer, H., and Hohmann, E., Z. anorg. allgem. chem., 241, 268-72 (1939)

B 95. Bonneman, P., and Bassiere, M., Compt. rend., 206, 1379-80 (1938)

B 96. Boon, J.W., Rec. trav. chim., 63, 32 (1944)

B 97. Boon, J.W., Rec. trav. chim., 63, 69 (1944)

B 98. Boon, J.W. and MacGillavry, C.H., Rec. trav. chim., 61, 910-20 (1942); Chem. Zentr., 1943, I, 2382

B 99. Booth, H.S. and Walkup, J.H., J.A.C.S., 65, 2334-9 (1943)

B100. Borchert, W., and Keidel, J. Heidelberg. Beitr. Mineral. u. Petrog. 1, 17-30 (1947)

B101. Borchert, W. and Schroeder, R., Heidelberg. Beitr. Mineral. u. Petrog. 1, No. 1, 112-17 (1947)

B102. Boss, A.E., and Hopkins, B.S., J.A.C.S., 50, 298-300 (1928)

B103. Botvinkin, O.K., Popova, T.A., Manuilova, N.S., Trans. 2nd. Conf. Exper. Min., Acad. Sci., U.S.S.R., 1937, 87-101

B104. Boucher, L. Le, An. soc. Espan. fis. quim., 26, 223-7 (1928)

B105. Boulle, A., Compt. rend., 206, 517-8 (1938)

B106. Bowen, N.L., Am. J. Sci., (4), 43, 115-32 (1917)

B107. Bowen, N.L., J. Phys. Chem., 30, 722-5, 726-35, 736-7 (1926)

B108. Bowen, N.L., and Greig, J.W., J. Am. Ceram. Soc., I, 238-54 (1924)

B109. Bowen, N.L., and Greig, J.W., Am. J. Sci., (5), 10, 204-12 (1925)

B110. Bowen, N.L., Greig, J.W., and Zies, E.G., J. Washington Acad. Sci., 14, 183-91 (1924)

B111. Bowen, N.L., and Schairer, J.F., Am. J. Sci., (5), 18, 301-12 (1929)

B112. Bowen, N.L., and Schairer, J.F., Am. J. Sci., (5), 18, 365-74 (1929)

B113. Bowen, N.L., and Schairer, J.F., Am. Mineral. 20, 543-51 (1935)

B114. Bowen, N.L., and Schairer, J.F., Am. J. Sci., (5), 29, 151-217 (1935)

B115. Bowen, N.L., Schairer, J.F. and Posnjak, E., Am. J. Sci., (5), 25, 273-97 (1933)

B116. Bowen, N.L., Schairer, J.F., and Posnjak, E., Am. J. Sci., (5), 26, 193-284 (1933)

B117. Bowen, N.L., Schairer, J.F., and Willems, H.W.V., Am. J. Sci., (5), 20, 405-55 (1930)

B118. Brammall, A., Leech, J.G.C. and Bannister, F.A., Mineral. Mag. J. mineral. Soc. 24 (1937) 507-20

B119. Brandt, K., Arkiv. Kemi, Min. Geol., 17A, No. 6, 1 (1943)

B120. Brauer, G., Z. anorg. allgem. chem. 248, 1-31 (1941)

B121. Braune, H., and Knoke, S., Z. Phys. Chem., 135, 49-62 (1928)

B122. Brauns, R., Centr. Min. Geol., 1927 A, 266

B123. Bredig, M.A., J. Phys. Chem. 46, 801 (1942)

B124. Bredig, M.A., Am. Mineral. 28, 600 (1943)

B125. Brendler, W., Am. Mineral., 19, 28-31 (1934)

B125a Bretscher, E., Cook, G.B., Martin, G.R. and Wilkinson, D.H., Proc. Roy. Soc., 196, 436 (1949)

B126. Brewer, L., J. Chem. Phys., 16, 1165 (1948)
B127. Briscoe, H.V.A., Evans, C., and Robinson, P.L., J. Chem. Soc., (London), 135, 1100-3 (1932)
B128. Briscoe, H.V.A., Robinson, P.L., and Smith, H.C., J. Chem. Soc., (London), 130, 282-90 (1927)
B129. Broch, E., Z. Phys. Chem., 1 B, 409-21 (1928)
B130. Broch, E., Z. Phys. Chem., 6 B, 22-6 (1929)
B131. Broch, E., Z. Phys. Chem., 20 B, 345-50 (1933)
B132. Brosset, C., Z. anorg. allgem. chem., 235, 139-47 (1937)
B133. Brosset, C., Z. anorg. allgem. chem., 239, 301-4 (1938)
B134. Brosset, C., Separate (Stockholm), 1942, 120 pp. (in Swedish)
B135. Brosset, C., Nature, 156, 451 (1945)
B136. Broun, A.S., J. Gen. Chem., (U.S.S.R.), 3, 998-1000 (1933)
B137. Brownmiller, L.T., Am. Mineral., 12, 43-8 (1927)
B138. Brownmiller, L.T., Am. J. Sci., (5), 29, 260-77 (1935)
B139. Brownmiller, L.T., and Bogue, R.H., Am. J. Sci., (5), 23, 501-24 (1932) Bur. Stand. J. Res., 8, 279 (1932)
B140. Brukl, A. and Ortner, G., Monatsh. Chem., 56, 358-64 (1930)
B141. Brukl, A., and Ortner, G., Z. anorg. allgem. chem., 203, 23-5 (1932)
B142. Brun, E., Arch. sc. Phys., 13, 352 (1902)
B143. Brun, E. and Jaffray, J., Compt. rend., 217, 371-2 (1943)
B144. Brunovskii, B.K., Mineralog. Abs. 6, 180 (1936)
B145. Buddington, A.F., Am. J. Sci., (5), 3, 35-87 (1922)
B146. Budnikov, P.P. and Palatnik, L.S., J. Phys. Chem., (U.S.S.R.), 10, 719-24 (1937)
B147. Buessem, W., and Eitel, A., Z. Krist., 95, 175-88 (1936)
B148. Buessem, W., and Gallitelli, P., Z. Krist., 96, 376-80 (1937)
B149. Bunting, E.N., J. Am. Ceram. Soc., 13, 5-10 (1930)
B150. Bunting, E.N., Bur. Stand. J. Res., 6, 948 (1931)
B151. Bunting, E.N., Bur. Stand. J. Res., 8, 279-87 (1932)
B152. Bunting, E.N., Bur. Stand. J. Res., 11, 719-25 (1933)
B153. Bunzel, E.G. and Kohlmeyer, E.J., Z. anorg. chem., 254, 1-30 (1947)
B154. Burbank, R.D. and Evans, H.T., Jr., Acta. Cryst. 1, 330 (1948)
B155. Bureau, J., Ann. chim., 8, 5-142 (1937)
B156. Burges, G.K., Bur. Stand. J. Res., 1, 635-40 (1928)
B157. Burke, J.E. and Smith, C.S., J.A.C.S. 69, 2500 (1947)
B158. Burri, C., Jakob, J., Parker, R.L., and Strunz, H., Chem. Abs., 30, 2138 (1936)
B159. Buschendorf, F., Z. phys. chem., 14B, 297 (1931)
B160. Buttgenbach, H., Chem. Abs., 28, 6658^7 (1934)
B161. Bye, J., Bull. soc. chim. 10, 239-44 (1943)
B162. Bystroem, A., Arkiv. Kemi, Min. Geol., 17B, No. 4, 1 (1943)
B163. Bystroem, A., Arkiv. Kemi, Min. Geol., 17B, No. 8, 1 (1943)
B164. Bystroem, A., Arkiv. Kemi, Mineral. Geol. 24A, No. 33, 18 pp. (1947) (in English)
B165. Bystroem, A., Hoek, B., and Mason, B., Arkiv. Kemi, Mineral. Geol., 15B, No. 4, 8 pp. (1941); Chem. Abs., 36, 308 (1942)
B166. Bystroem, A. and Westgren, A., Arkiv. Kemi, Min. Geol., 17B, No. 2, 1 (1943)

C 1. Cady, G.H., J.A.C.S., 56, 1431-4 (1934)
C 2. Caglisti, V., Atti. Accad. Lincei., 22, 146-9 (1935)
C 3. Caillere, S., Compt. rend., 219, 256 (1944)
C 4. Calcagni, C.G., Gazz. chim. ital., 50, I, 250 (1920)
C 5. Cambi, L., and Bozza, G., Ann. chim. applic., 13, 221 (1923)
C 6. Cameron, F.K., and McCaughey, W.J., J. Phys. Chem., 15, 463-70 (1911)
C 7. Campbell, A.N., J.A.C.S. 65, 2268-71 (1943)
C 8. Campbell, A.N., and Campbell, A.J.R., Trans. Faraday Soc., 31, 1567-74 (1935)
C 9. Campbell, A.N. and Epstein, S., J.A.C.S. 64, 2679 (1942)
C10. Canneri, G., and Morelli, R., Atti. Accad. Lincei, Roma, (5), 31, I 109-11 (1922)
C11. Carli, F. de, Atti. Linc., (6), 5, 44 (1927)
C12. Carlson, E.T., Bur. Stand. J. Res., 9, 825-32 (1932)
C13. Carlson, E.T. and Wells, L.S., J. Res. Natl. Bur. Standards, 41, 103 (1948)
C14. Carnelley, T., J. Chem. Soc., (London), 26, 323-339 (1873)
C15. Carpenter, C.D., Chem. Metal. Eng., 24, 569-71 (1921)
C16. Carriere, E., Guiter, H., and Fruchier, R., Bull. soc. chim., 11, 535-6 (1944)
C17. Casasopra, S., Schweiz. Mineral. Petrog. Mitt., 18, 441-9 (1938)
C18. Castel, P., Compt. Rend., 208, 519-20 (1939)
C19. Centnershver, M., and Blumenthal, M., Bull. intern. acad. polonaise, Classe. sci. math. nat., 1933 A, 499-522
C20. Chapman, C.A., Am. Mineral. 28, 90-8 (1943)
C21. Cheesman, G.H., J. Chem. Soc., (London), 133, 35-7 (1930)
C22. Chelishcheva, A.G., Compt. rend. acad. sci., U.R.S.S., 28, 508-11 (1940)
C23. Chikashige, M., Z. anorg. allgem. chem., 54, 50-7 (1907)
C24. Chikashige, M., and Aoki, T., Mem. Coll. Sci. Kyoto. Imp. Univ., 2, 249-54 (1917)
C25. Chikashige, M., and Hikosaka, R., Mem. Coll. Sci., Kyoto. Imp. Univ., 2, 239-44 (1917)
C26. Chikashige, M., and Kurosawa, R., Mem. Coll. Sci. Kyoto Imp. Univ., 2, 245-8 (1917)
C27. Christoffers, H.J., Lingafelter, E.C. and Cady, G.H., J.A.C.S. 69, 2502 (1947)
C28. Chudoba, K. and Stackelberg, M.v., Z. Kryst., 95, 230-46 (1936)
C29. Chudoba, K., and Wisfeld, W., Centr. Mineral. Geol., 1933 A, 323-6
C30. Clark, C.B., J. Am. Ceram. Soc., 29, 25 (1946)
C31. Clark, G.L., and Buckner, H.K., J.A.C.S., 44, 230-44 (1922)
C32. Clark, G.L., and Gross, S.T., Z. Krist., 98, 107-11 (1937)
C33. Clark, G.L., and Reynolds, D.H., Z. Krist., 98, 185-90 (1937)
C34. Clark, G.L., and Rowin, R., J.A.C.S., 63, 1299-1310 (1941)
C35. Clark, G.L., Schieltze, N.C., and Quirke, T.T., J.A.C.S., 59, 2305 (1937)
C36. Clark, G.L., and Tyler, W.P., J.A.C.S., 61, 58-65 (1939)
C37. Clark, H.K. and Hoard, J.L., J.A.C.S. 65, 2115-19 (1943)
C38. Clarke, F.W., Am. J. Sci., (3), 14, 280-6 (1877)

C39. Clausen, H., Z. Krist., 95, 394-403 (1936)
C40. Clayton, J.O., and Giauque, W.F., J.A.C.S., 54, 2610-26 (1932)
C41. Clouse, J.H., Z. Krist., 76, 285-6 (1930)
C42. Cocksedge, H.E., U.S. Patent 1,583,660, (1922) Issued May 4, 1926
C43. Cogne, G., Compt. rend., 206, 1119-20 (1938)
C44. Cohen, E., and Addink, N.W.H., Z. phys. chem., 168 A, 188-201 (1934)
C45. Cohen, E. and Bredee, H.L., Z. phys. chem., 140, 391-405 (1929)
C46. Cohen, E., and Helderman, W.D., Z. phys. Chem., 113, 145-56 (1924)
C47. Cohn, W.M., and Tolksdorf, S., Z. phys. Chem., 8B, 331-56 (1930)
C48. Colby, M.Y., and Harper, J.P., Z. Krist., 89, 191 (1934)
C49. Cole, S.S., and Espenschied, H., J. Phy. Chem., 41, 445-51 (1937)
C50. Cole, S.S., and Nelson, W.K., J. Phys. Chem., 42, 245-51 (1938)
C51. Cole, S.S., Scholes, S.R., and Amberg, C.R., J. Am. Ceram. Soc., 18, 58-61 (1935)
C52. Cole, S.S., and Taylor, N.W., J. Am. Ceram. Soc., 18, 82-5 (1935)
C53. Copeland, L.C. and Short, C.A., J.A.C.S., 62, 3285-91 (1940)
C54. Corio, Z. Krist., 32, 524 (1900)
C55. Craig, W.M. and Drake, G.W., J.A.C.S., 56, 584-5 (1934)
C56. Crane, E.J., Chem. Eng. News., 24, 1233 (1946)
C57. Cranston, J.A., and Livingstone, A.Y., J. Chem. Soc., (London), 129, 501-3 (1926)
C58. Crespi, M., and Moles, E., Annles. soc. esp. fis. Quim., 20, 555-62 (1922)
C59. Crespi, M., and Moles, E., Annles. soc. esp. fis. Quim,, 21, 305 (1923)
C60. Crookes, W., Lieb. Ann., 78, 177 (1851)
C61. Cueilleron, J., Ann. chim. 19, 459 (1944)
C62. Cueilleron, J., Compt. rend. 219, 209 (1944)
C63. Curie, M., Compt. rend., 175, 617-9 (1922)
C64. Curti, R., Gazz. Chim. Ital., 68, 702-8 (1938)

D 1. D'Achiardi, G., Period. Mineral. Roma, 5, 22-32 (1934)
D 2. Dahl, A. and Van Dusen, M.S., J. Research Natl. Bur. Standards 39, No. 1, 53-8 (1947) (R.P. No. 1813)
D 3. Daniels, F., and Bright, A.C., J.A.C.S., 42, 1131-41 (1920)
D 4. D'Ans, J., and Loeffler, J., Z. anorg. allgem. chem., 191, 1-35 (1930)
D 5. Davis, H.M. and Knight, M.A., J. Am. Ceram. Soc., 28, 97, 100 (1945)
D 6. Dawihl, W., and Schroeter, K., Z. anorg. allgem. chem., 233, 178-83 (1937)
D 7. Day, A.L., Geophysical Lab., Carnegie Inst. Washington, (Paper No. 833); Year Book No. 32, 59-79 (1932/33)
D 8. Day, A.L., and Shepherd, E.E., Am. J. Sci., (4), 22, 265-302 (1906)
D 9. Day, A.L., and Shepherd, E.S., J.A.C.S., 28, 1089-1114 (1906)

D10. Day, A.L., and Sosman, R.B., Am. J. Sci., (4), 31, 341-9 (1911)
D11. Day, A.T. and Allen, E.T., Am. J. Sci., (4), 19, 91-142 (1905)
D12. Demassieux, N., and Federoff, B., Compt. rend., 206, 1649-51 (1938)
D13. Demassieux, N., and Fedoroff, B., Compt. rend., 208, 1223-5 (1939)
D14. Denbigh, K.G., and Gray, R.W., J. Chem. Soc., (London), 137, 1346-52 (1934)
D15. Dennis, L.M., and Hulse, R.E., J.A.C.S., 52, 3553-6 (1930)
D16. Dennis, L.M., and Laubengayer, A.W., Z. phys. chem., 130, 520-31 (1927)
D17. Dergunov, E.P. and Bergman, A.G., Doklady Akad. Nauk. S.S.R. 60, 391-4 (1948)
D18. Dergunov, E.P., Doklady Akad. Nauk. S.S.S.R. 60, 1185-8 (1948)
D19. Deverin, L., Bull. Soc. Vand., 56, 545 (1928)
D20. Dewar, Chem. News, 85, 277 (1902)
D21. Dihlstroem, K., Z. anorg. allgem. chem., 239, 57-64 (1938)
D22. Dilaktorskii, N.L., Mem. soc. russe mineral., (2), 68, No. 1, 18-26 (1939); Chem. Abs., 34, 5018 (1940)
D23. Dilkatorskii, N. L. and Kadenskii, A.A., Trudy Tret'ego Soveskchaniya Epsptl. Mineral. i Petrog., Inst. Geol. Nauk, Akad. Nauk S.S.S.R. 1940, 217-21; Khim. Referat. Zhur. 4, No. 1, 38 (1941); cf. C.A. 34, 5018^4
D24. Dittler, E., and Hofmann, A., Chem. Erde, 11, 256-77 (1937)
D25. Dittler, E., and Lasch, H., Sitzber. Akad. Wiss. Wien, Math-naturw. Abt. I, 140, (8), 633-74 (1931)
D26. Doelter, C., and Dittler, E., Ber. Kais. Akad. Wiss., Wien, 121, I 903 (1912)
D27. Domange, L., Bull. Soc. Chim., 6, 1452-9 (1939)
D28. Donnay, J. D.H. and Melon, J., Proc. Natl. Acad. Sci. 20, 327-35 (1934)
D29. Donohue, J. and Helmholz, L., J. Am. Chem. Soc. 66, 295-8 (1944)
D30. Dorsey, N.E., Properties of Ordinary Water Substance, A.C.S. Monograph Series 81, Reinhold Publishing Corp., New York, N.Y., 1940
D31. Douglas, J.A., Quart. J. Geol. Soc., 63, 145 (1907)
D32. Dow Corning Corporation Publication
D33. Druzhinin, I.G., Compt. rend. acad. sci., U.S.S.R., 23, 921-4 (1939)
D34. Duboin, A., Compt. rend., 120, 678-81 (1895)
D35. Duboin, A., Compt. rend., 181, 336-7 (1925)
D36. Dubois, P., Compt. rend., 199, 1416-8 (1934)
D37. Dubois, P., and Breton, P., Compt. rend., 206, 1969-72 (1938)
D38. DuMond, J.W.M. and Cohen, E.R., Rev. Med. Phys., 20, 107 (1948)
D39. Durand, J.F., Bull. soc. chim., (5), 3, 1382-8 (1936)
D40. Durand, M.A., Phys. Rev., (2), 50, 449-455 (1936)
D41. DuRietz, T., Geol. Fören.i Stockholm Förh. 67, 78-9 (1945); Mineralog. Abstracts 9, 188 (1946)
D42. Durrell, C., Am. Mineral., 25, 501-2 (1940)
D43. Dyckerhoff, W., Zement, 13, 400 (1924)

E 1. Eastman, E.D., Brewer, L., Bromley, L.A., Gilles, P.W. and Lofgren, N.L., Declassified Manhattan Proj. Document of July 24, 1945. (Preparation and Properties of sulfides and Oxide-sulfides of Uranium)
E 2. Ebelmen, J.J., Am. Chim. Phys., 33 (iii), 34 (1851)
E 3. Ebert, F. and Woitinek, H., Z. anorg. allgem. chem., 210, 269-72 (1933)
E 4. Edmister, F.H., and Cooper, H.C., J.A.C.S., 42, 2419-34 (1920)
E 5. Eiger, A., Chem. Abs., 31, 7781 (1937)
E 6. Einecke, E., Die Chemie, 55, 40 (1942)
E 7. Eissner, W., Dissertation, Leipzig, 1913, 1-50, J. Chem. Soc. 106, II, 138
E 8. Eitel, W., Schriften Königsberger gelehrt. Ges., 1, 159 (1924)
E 9. Eitel, W., Neues Jahrb. Min., Beil., 48, 63 (1923)
E10. Eitel, W., Z. Krist., 60, 595 (1924)
E11. Eitel, W., Neues Jahrb. Min. Beil., 51, 477 (1925)
E12. Eitel, W., Zement. 27, 455-59, 469-72 (1938)
E13. Eitel, W., and Skaliks, W., Z. anorg. allgem. chem., 183, 263-86 (1929)
E14. Eitel, W., and Troemel, G., Fortschr. Min., 14, 28-33 (1929)
E15. Elliott, L.D., J. Phys. Chem., 28, 887-8 (1924)
E16. Elliott, N., J.A.C.S., 59, 1958-62 (1937)
E17. Endo, K., Sci. Repts. Tohoku. Imp. Univ., 1st. Ser., 25, 879-920 (1937)
E18. Eppler, Z. Krist., 30, 134 (1899)
E19. Ernst, T., Z. phys. chem., 208, 65-88 (1933)
E20. Erway, N.D. and Seifert, R.L., M.D.D.C. 1030, Sept. 24, 1946 Technical Information Division, Oak Ridge, Tenn.
E21. Eskola, P., Am. J. Sci., (5), 4, 331-75 (1922)
E22. Ettinger, J., Z. anorg. allgem. chem., 206, 260-2 (1932)
E23. Evans, H.T., J.A.C.S. 70, 1291-2 (1948)
E24. Evdokionova, K.A. and Bergman, G.A., Akad. Nauk S.S.S.R., Referaty, Otdel. Khim. Nauk 1945, 43
E25. Ewell, R.H., Bunting, E.N. and Geller, R.F., Bur. Stand. J. Res., 15, 551-6 (1935)
E26. Ewing, W.W., Brandner, J.D., Slichter, C.B. and Griesnigen, W.K., J.A.C.S., 55, 4822-4 (1933)
E27. Ewing, W.W., McGovern, J.J., and Mathews, Jr. G.E., J.A.C.S., 55 4827-30 (1933)

F 1. Fahey, J.J., Am. Mineral., 24, 514-8 (1939)
F 2. Faller, F.E., Blitz, W., Meisel, K. and Zumbusch, M., Z. anorg. allgem. chem. 248, 209-28 (1941); Chem. Zentr. 1942, I, 1091-2; cf. C.A. 36, 1253^{9}
F 3. Fang, S.M., J. Am. Ceram. Soc., 20, 214 (1937)
F 4. Faust, G.T., Am. Mineral., 21, 735-63 (1935)
F 5. Fedotieff, P.P., Z. anorg. allgem. chem., 167, 329-40 (1927)
F 6. Fedotieff, P.P., and Iljinsky, W., Z. anorg. allgem. chem., 80, 113-54 (1913)
F 7. Fedotieff, P.P., and Timofeeff, K., Z. anorg. allgem. chem., 206, 263-6 (1932)

F 8. Feher, F., Angew. Chem. 51, 497-498 (1938)
F 9. Feitknecht, W. and Gerber, W., Helv. Chim. Acta 28, 1444 (1945)
F10. Fenoglio, M., Period Mineral. I, 1 (1936)
F11. Ferguson, J.B., and Buddington, A.F., Am. J. Sci., (4), 50, 131-40 (1920)
F12. Ferguson, J.B., and Merwin, H.E., Am. J. Sci., (4), 48, 81-123 (1919)
F13. Ferguson, J.B., and Merwin, H.E., Am. J. Sci., (4), 48, 165-89 (1919)
F14. Ferguson, J.M., J. West Scot. Iron Steel Inst., 42, 13-23 (1934)
F15. Ferguson, R.B., Trans. Roy. Soc. Can. 40, Sect. IV, 11-25 (1946)
F16. Fernelius, W.C., Chem. Eng. News, 26, 161 (1948)
F16a Ferrari, A., and Colla, C., Gazz. Chim. Ital., 67, 88-94 (1937)
F17. Finholt, A.E., Bond, A.C. Jr., Wilzbach, K.E. and Schlesinger, H.I., J.A.C.S. 69, 2692 (1947)
F18. Fischer, E., Z. Krist. 105, 268 (1944)
F19. Fischer, E., Neues Jahrb. Mineral. Geol. Monatsh. A, 1945-48, 44-6
F20. Fischer, J., Z. anorg. allgem. chem., 219, 367-75 (1935)
F21. Fischer, W., and Biltz, W., Z. anorg. allgem. chem., 176, 81-111 (1928)
F22. Fischer, W., and Gewehr, R., Z. anorg. allgem. chem., 222, 303-11 (1935)
F23. Fischer, W., and Gewehr, R., Z. anorg. allgem. chem., 242, 188-92 (1939)
F24. Fischer, W., Gewehr, R., and Wingchen, H., Z. anorg. allgem. chem., 242, 161-87 (1939)
F25. Fischer, W., and Weidemann, W., Z. anorg. allgem. chem., 213, 106-114 (1933)
F26. Flink, G., Z. Krist., 18, 361-76 (1891)
F27. Flint, E.P. and Wells, L.S., J. Res. Natl. Bur. Stand. 33, 471 (1945)
F28. Flint, E.P., McMurdie, H.F. and Wells, L.S., Bur. Stand. J. Res., 21, 617-38 (1938)
F29. Flint, E.P., McMurdie, H.F., and Wells, L.S., Bur. Stand. J. Res., 26, 13-33 (1941)
F30. Flint, E.P., and Wells, L.S., Bur. Stand. J. Res., 17, 727-52 (1936)
F31. Flood, H., Gørrissen, J., and Veimo, R., J.A.C.S., 59, 2494-5 (1937)
F32. Flusion, G., and Sall, C., Compt. rend., 201, 451-3 (1935)
F33. Foersterling and Philipp, Dent. Pat. 193,560 (1905)
F34. Foëx, M., Compt. rend. 220, 359 (1945)
F35. Foëx, M. and Loriers, J., Compt. rend. 226, 901-3 (1948)
F36. Foote, F., and Jette, E.R., Phys. Rev., 58, 81-6 (1940)
F37. Forbes, G.S., and Anderson, H.H., J.A.C.S., 62, 761-3 (1940)
F38. Forbes, G.S., and Anderson, H.H., J.A.C.S., 66, 1703-6 (1944)
F39. Forcrand, R.H.de, Compt. rend., 147, 166 (1908), Ann. Chim. Phys. 15, (8), 455 (1908)
F40. Forcrand, R.de, Compt. rend., 152, 1073-7 (1911)
F41. Ford, W.E., Trans. Connect. Acad. Sci., 22, 213 (1917)

F42. Formstecher, M. and Ryskevic, E., Compt. rend., 221, 558 (1945)
F43. Formstecher, M. and Ryskevic, E., Compt. rend., 221, 747 (1945)
F44. Forrest, J.W., J.Optical Soc. Am. 32, 382 (1942)
F45. Foshag, W.F., Am. Mineral., 19, 268-74 (1934)
F46. Foshag, W.F., Am. Mineral., 20, 50-6 (1935)
F47. Foshag, W.F., and Hess, F.L., Proc. U.S. Natl. Mus., 72, 1-12 No. 2707 (1927)
F48. Foster, W.R. and Royal, H.F., J. Am. Ceram. Soc. 32, 26 (1949)
F49. Fowle, F.E., Smithsonian Physical Tables, 8th. Ed., 1933
F50. Frank, H.H., Bredig, M.A., and Kanert, E., Z. anorg. allgem. chem., 237, 49-78 (1938)
F51. Fredenhagen, K., Z. anorg. allgem. chem., 210, 210-24 (1933)
F52. Fredenhagen, K., and Dahmlos, J., Z. anorg. allgem. chem., 179, 77-88 (1929)
F53. Frevel, L.K., Ind. & Eng. Chem., 14, 687 (1942)
F54. Frey, G.S., Z. Elektrochem., 36, 511-23 (1930)
F55. Fricke, R., Z. anorg. allgem. chem. 166, 244-56 (1927)
F56. Fricke, V.R. and Seitz, A., Z. anorg. chem., 254, 107-15 (1947)
F57. Fricke, R. and Seitz, A., Z. anorg. chem., 255, 13 (1947)
F58. Fricke, R. and Severin, H., Z. anorg. allgem. chem., 205, 287-308 (1932)
F59. Fried, S. and Davidson, N.R., J.A.C.S. 70, 3539-47 (1948)
F60. Fried, S. and Davidson, N.R., M.D.D.C. 1659
F61. Friederich, E., and Sittig, L., Z. anorg. allgem. chem., 145, 127-40 (1925)
F62. Friedrich, K., Metallurgie, 7, 323-32 (1910)
F63. Friedrich, K., Metall u. Erg., 11, 160-7 (1914)
F64. Friedrich, O.M., and Robitsch, J., Centr. Mineral. Geol., 1939 A, 142-55
F65. Friend, J.N., Textbook of Inorganic Chemistry, 11 volumes, Charles Griffin and Co., London. 1914-
F66. Friend, J.N., J. Chem. Soc., (London), 138, 824-6 (1935)
F67. Friend, J.N., J. Chem. Soc., (London), 138, 1430-2 (1935)
F68. Frölich, A., Trans. Chalmers Univ. Tech. Gothenburg, Sweden, No. 49, 3 (1946)
F69. Frondel, C., Am. Mineral., 26, 145-52 (1941)
F70. Frondel, C., Am. Mineral., 28, 521 (1943)
F71. Frondel, C., Am. Mineral., 32, 84-7 (1948)
F72. Frondel, C. and Pough, F.H., Am. Mineral. 29, 211-25 (1944)

G 1. Gabriel, A., J.A.C.S., 57, 686-8 (1935)
G 2. Gallitelli, P., Chem. Abs., 28, 6357 (1934)
G 3. Gallup, J., J. Am. Ceram. Soc., 18, 144-8 (1935)
G 4. Garnett, C.S., Mineral. Mag., 20, 151-7 (1923)
G 5. Gaskell, T.F., Z. Krist., 96, 203-13 (1937)
G 6. Gaubert, P., Compt. rend. congr. Soc. Sav. Sci., 1925
G 7. Gaubert, P., Bull. soc. franc. mineral., 50, 504-15 (1927)
G 8. Gaubert, P., Compt. rend., 197, 72-5 (1933)
G 9. Gaudin, A.M., and Hamly, W.T., Econ. Geol., 33, 868-88 (1938)
G10. Geilmann, W., and Wrigge, W., Z. anorg. allgem. chem., 197, 375-82 (1931)

G11. Gel'd. P.V. and Kochnev, M.I.,Doklady Akad. Nauk S.S.S.R. 61, 649-52 (1948)
G12. Geller, R.F.,Bur. Stands. J. Res., 27, 555-66 (1941)
G13. Geller, R.F., and Bunting, E.N.,Bur. Stand. J. Res., 17, 277-88 (1936)
G14. Geller, R.F., and Bunting, E.N.,Bur. Stand. J. Res., 18, 585-93 (1937)
G15. Geller, R.F., and Bunting, E.N.,Bur. Stand. J. Res., 23, (2), 275-83 (1939)
G16. Geller, R.F., and Bunting, E.N.,J. Research Natl. Bur. Standards 31, 255-70 (1943); R.P. No. 1564
G17. Geller, R.F., Creamer, A.S., and Bunting, E.N.,Bur. Stand. J. Res., 13, 237-44 (1934)
G18. Geller, R.F., and Yavorsky, P.J.,J. Res. Natl. Bur. Stand. 34, 395 (1945)
G19. Geller, R.F., Yavorsky, P.J., Steierman, B.L., and Creamer, A.S.,J. Research. Natl. Bur. Standards, 36 (3), 277-312 (1946); R.P. 1703
G20. Genet, P.,Compt. rend., 205, 732-4 (1937)
G21. Gerasimov, Y.I., Sluchank, B.S., and Gamburg, L.V.,J. Phys. Chem., (U.S.S.R.), 13, 1531-7 (1939)
G22. Gerasimovskii, V.I.,Compt. rend. acad. sci., U.R.S.S., 22, 259-63 (1939) .
G23. Ghira, A.,Z. Phys. Chem., 12, 764-6 (1893)
G24. Giauque, W.F., and Powell, T.M.,J.A.C.S., 61, 1970-4 (1939)
G25. Giauque, W.F., and Stephenson, C.C.,J.A.C.S., 60, 1389-94 (1938)
G26. Gibson, R.E., Wyckoff, R.W.G., and Merwin, H.E.,Am. J. Sci., (5), 10, 325-333 (1925)
G28. Gilfillan, Jr., E.S.,J.A.C.S., 56, 2201 (1934)
G29. Gill, A.F.,Can. J. Res., 10, 703-12 (1934)
G30. Gillespie, L.J. and Gerry, H.T.,J.A.C.S., 53, 3962-8 (1931)
G31. Ginsberg, H.,Z. anorg. allgem. chem., 204, 225-31 (1932)
G32. Ginsberg, and Nikogossian, Bull. com. geol. Leningrad, 43, 397 (1924)
G32a Giquere, P.A.,Can. J. Research 21B, No. 8, 156 (1943)
G33. Giusca, D. and Popescu, I.,Bull. soc. roumaine phys. 40, No.73, 13-24 (1939)
G34. Giusca, D.,Chem. Abs., 31, 6527 (1937)
G35. Giusca, D., and Popescu, I.,Chem. Abs., 34, 7695^9 (1940)
G36. Gloser, O.,Cent. Mineral. Geol. Abt. A 1926, 81-96
G37. Glatzel, A.,Ueber dimetaphosphorsaure und tetrametaphosphorsaure Salze,Diss., Wiirzburg, 1880
G38. Glemser, O., and Gwinner, E.,Z. anorg. allgem. chem., 240, 161-6 (1939)
G39. Glixelli, S., and Boratynski, K.,Z. anorg. allgem. chem., 235, 225-41 (1938)
G40. Gmelins Handbuch der anorgani- schen chemie, 7th Ed., edited by C. Friedheim, 6 volumes. Carl Winter's Universitaetsbuchhandlung, Heidelberg. 1906-1924

G41. Gmelins Handbuch der anorgani- schen chemie, 8th Ed., edited by R.J. Meyer, Verlag Chemie, Berlin, 1924-
G42. Godlevskii, M.,Mem. soc. russe mineral., 66, 315-44 (1937)
G43. Godlevskii, M.N.,Compt. rend. acad. sci., U.R.S.S., 28, 638-40 (1940)
G44. Godlevskii, M.N. and Ivanov, A.A.,Compt. rend. acad. sci. U.R.S.S. 32, 351 (1941)
G45. Goldschmidt, V.M.,Trans. Faraday Soc., 25, 253-83 (1929)
G46. Goldschmidt, V.M., and Hauptmann, H.,Nachr. Ges. Wiss. Goett., 1932, 53-72
G47. Goldsmith, J.R., J. Geol. 56, 80-1 (1948)
G48. Goldsztaub, S., Compt. rend., 196, 280-2 (1933)
G49. Goldsztaub, S., Bull. Soc. Franc. Mineral., 58, 6-78 (1935)
G50. Golovkov, M.P., Klement'ev, V.A., Mikhailova, M.N., and Obukhov, A.P.,Trans. State Inst. Applied Chem., (U.S.S.R.), No. 23, 17-30 (1935)
G51. Goodeve, C.F., and Powney, J., J. Chem. Soc., (London), 135, 2078-81
G52. Goranson, R.M., and Kracek, F.C., J. Phys. Chem., 36, 913-26 (1932)
G53. Goranson, R.M., and Kracek, F.C., J. Phys. Chem., 3, 87-92 (1935)
G54. Gordon, S.G., Proc. Acad. Nat. Sci. Phila. 96, 279 (1944)
G55. Gorshkov, G.S., Compt. rend. acad. sci. U.R.S.S. 33, 254 (1941)
G56. Gossner, B., Z. Kryst., 35, 147 (1904)
G57. Gossner, B., Z. Krist., 38, 148 (1904)
G58. Gossner, B. and Drexler, K., Z. Krist., 91, 494-500 (1935)
G59. Goubeau, J., Kolb, H., and Krall, H.G., Z. anorg. allgem. chem. 236, 45-56 (1938)
G60. Graham, T., Lieb. Ann. Chem., 29, 24 (1839)
G61. Grahmann, W., Z. anorg. allgem. chem., 81, 257-314 (1913)
G62. Greene, K.T., J. Research Natl. Bur. Standards 32, No. 1, 1-10 (1944) (R.P. No. 1570)
G63. Greene, K.T. and Bogue, R.H., J. Research Natl. Bur. Standards, 36 (2) 185-207 (1946); R.P. 1699
G64. Greene, K.T. and Morgan, W.R., J. Amer. Ceram. Soc., 24, (4), 111-6 (1941)
G65. Greer, W.L.C., Am. Mineral., 17, 135-42 (1932)
G66. Greig, J.W., J.A.C.S., 54, 2846-9 (1932)
G67. Greig, J.W., and Barth, T.F.W., Am. J. Sci., (5), 35A, 93-112 (1938)
G68. Grieve, J., and White, J., J. Roy. Tech. Coll., Glasgow, 4, part 3, 441-8 (1939)
G69. Grieve, J., and White, J., J. Roy. Tech. Coll., (Glasgow), 4, 660-70 (1940)
G70. Grigoriev, D.P., Cent. Min. Pet. Geol., 1935, 117
G71. Grigor'ev, D.P., Chem. Abs., 31, 6540 (1937)
G72. Grimm, H.G., Z. Phys. Chem., 2B, 181-99 (1929)
G73. Grimm, H.G., and Metzger, H., Ber. 69B, 1356-64 (1936)
G74. Grønvold, F., Nature 162, 70 (1948)
G75. Grønvold, F. and Haraldsen, H., Nature 162, 69 (1948)

G76. Groschuff, E., Ber., 36, 1783-95 (1903)
G77. Groschuff, E., Z. anorg. allgem. chem., 58, 102-12 (1908)
G78. Grosse, A.V., M.D.D.C. 1041 (April, 1944)
G79. Grube, G., and Stäsche, M., Z. Elektroch., 33, 482 (1927)
G80. Gruner, J.W., Am. Mineral., 21, 449-55 (1936)
G81. Gruner, J.W., Am. Mineral. 32, 654-9 (1947)
G82. Guerin, H., Compt. rend. 203, 997-8 (1936)
G83. Guerin, H., Compt. rend. 204, 1740-1 (1937)
G84. Guerin, H., Bull. soc. chim., (5), 4, 1472-81 (1937)
G85. Guertler, W., Z. anorg. allgem. chem., 38, 456-60 (1904)
G86. Guertler, W., Z. anorg. allgem. chem., 40, 337-54 (1904)
G87. Guilland, C, Michel, A., Benard, J., and Fallot, M., Compt. rend. 219, 58 (1944)
G88. Guimaraes, C.P., Mineracao e met. 8, 135 (1944)
G89. Guntz, A., and Martin, F., Bull. Soc. Chim., (4), 5, 1004-11 (1909)

H 1. Haase, M., Z. Kryst. 65, 509-87 (1927)
H 2. Haase, M., Z. phys. chem., 126, 118-126 (1927)
H 3. Haase, M., Z. Krist., 66, 236-8 (1928)
H 4. Haase, M., Z. Kryst. 68, 82-6 (1928)
H 5. Haegg. G., Z. Phys. Chem., 29B, 95-103 (1935)
H 6. Haegg, G. and Magneli, A., Arkiv Kemi, Mineral. Geol. 19A, No. 2, 14 pp. (1944)
H 7. Haigh, F.L., J.A.C.S., 34, 1137-59 (1912)
H 8. Hall, F.P., and Insley, H., J. Am. Ceram. Soc., 16, 459-567 (1933)
H 9. Hall, F.P., and Insley, H., J. Am. Ceram. Soc., 21, 113-64 (1938)
H10. Hall, F.P. and Insley, H., Phase Diagrams for Ceramists, Part II, Nov. Issue, Jour. Am. Ceram. Soc., 1947.
H11. Hampson, G.C., and Pauling, L., J.A.C.S., 60, 2702-7 (1938)
H12. Hannebohn, O., and Klemm, W., Z. anorg. allgem. chem., 229, 337-51 (1936)
H13. Hansen, W.C., and Brownmiller, L.T., Am. J. Sci., (5), 15, 225-42 (1928)
H14. Hansen, W.C., Brownmiller, L.T., and Bogue, R.H., J.A.C.S., 50, 396-406 (1928)
H15. Hantke, G., Z. ang. chem., 39, 1065-71 (1926)
H16. Hantzsch, A., Ber., 60, 1933-50 (1927)
H17. Hare, A., Phil. Mag., (6), 48, 412-21 (1924)
H18. Harkins, W.D., and Clark, G.L., J.A.C.S., 37, 1816-28 (1915)
H19. Harris, W. W. and Wolters, R.A., M.D.D.C.-1662, A.E.C., Abs. Dec. Doc., 11, 103 (1948)
H20. Hartford, W.H. and Lane, K.A., J.A.C.S. 70, 647-8 (1948)
H21. Harting, H., Z. Instrumentenk. 63, 125-31 (1943)
H22. Hartley, H., and Barrett, W.H., J. Chem. Soc., 95, 1178-85 (1909)
H23. Hassel, O., and Kringstad, H., Z. anorg. allgem. chem., 191, 36-42 (1930)
H24. Hassel, O. and Mark, H., Z. Physik 27, 89-101 (1924)

H25. Hassel, O., and Nilssen, S., Z. anorg. allgem. chem., 181, 172-6 (1929)
H26. Hatch, R.A., Am. Mineral. 28, 471-96 (1943)
H27. Hauptmann, H. and Novak, J., Z. phys. chem., 15B, 365 (1932)
H28. Hautefeuille, P., Compt. rend., 59, 732-5 (1864)
H29. Hautefeuille, P., Ann. Chim. Phys., (4), 4, 169 (1865)
H30. Hay, R., White, J., and McIntosh, A.B., J. West Scotland Iron and Steel Inst., 42, 99-104 (1934/1935)
H31. Hayek, E., Z. anorg. allgem. chem., 225, 47-8 (1935)
H32. Heckter, M., Glastech. Ber., 12, 156-72 (1934)
H33. Heide, F., Centr. Min. Geol., 1924,641-51
H34. Heinrick, E.M., Am. Mineral. 31, 71 (1946)
H35. Helms, A, and Klemm, W., Z. anorg. allgem. chem. 241 (1939) 97-106^2
H36. Helz, A.W., J. Am. Ceram. Soc., 22, 289-301 (1939)
H37. Hendricks, S.B., J. Phys. Chem., 30, 248-53 (1926)
H38. Hendricks, S.B., Z. Krist., 91, 48-64 (1935)
H39. Hendricks, S.B., and Albrecht, W.H., Ber., 61, 2153-61 (1928)
H40. Hendricks, S.B., Deming, W.E., and Jefferson, M.E., Z. Kryst., 85, 143-55 (1933)
H41. Hendricks, S.B., Posnjak, E., and Kracek, F.C., J.A.C.S., 54, 2766-86 (1932)
H42. Hendricks, S.B., and Wyckoff, R.W.G., Am. J. Sci., (5), 13, 491-6 (1927)
H43. Henglein, F.A., Z. Elektrochem., 30, 5-12 (1924)
H44. Henglein, F.A., and Roth, R., Z. anorg. allgem. chem., 126, 227-36 (1923)
H45. Henkel, P., and Klemm, W., Z. anorg. allgem. chem., 222, 65-6 (1935)
H46. Henkel, P., and Klemm, W., Z. anorg. allgem. chem., 222, 67-9 (1935)
H47. Herman, G., (and Sun, K.H.), Z. physik, chem. B35, 298-308 (1937), Sun calculated the B.P. of BaO from Herman's equation
H48. Herrmann, K., Strukturbericht, Band IV, V, VI and VII (Published 1941)
H49. Herrmann, K., and Ilge, W., Z. Krist, 75, 41-66 (1930)
H50. Herzenberg, R., Separate 4 pp. (1942) (in Spanish, printed by author, Oruro, Bolivia)
H51. Herzenberg, R., Bol. tec. fac. nac. ing. Univ. tec, Oruro 1946, No. 1, 11 pp.
H52. Hevesy, G.v., Z. phys. chem., 73, 667-84 (1910)
H53. Hevesy, G.v., Z. anorg. allgem. chem., 147, 217-32 (1925)
H54. Hevesy, G.v., Z. anorg. allgem. chem., 150, 68 (1926)
H55. Hevesy, G.v., and Dullenkoff, W., Z. anorg. allgem. chem., 221, 161-6 (1934)
H56. Hey, M.H., Mineral. Mag., 23, 243-89 (1932)
H57. Hey, M.H., and Bannister, F.A., Mineral. Mag., 23, 421-47 (1933)
H58. Hey, M.H., and Bannister, F.A., Mineral. Mag., 24, 227-53 (1936)
H59. Hibbs, J.G., J.A.C.S., 18, 1044-50 (1896)

H60. Hidnert, P., Natl. Bur. Stand. J. Res., 26, 81-91 (1941)
H61. Hidnert, P. and Blair, M.G., J. Research Natl. Bur. Standards, 30, 427-33 (1943) (R.P. No. 1541)
H62. Hill, E.G., and Sirkar, A.P., Proc. Roy. Soc., (London), 83A, 130-48 (1910)
H63. Hill, W.L., Faust, G.T., and Hendricks, S.B., J.A.C.S., 65, 794-802 (1943)
H64. Hill, W.L., Faust, G.T., and Reynolds, D.S., Am. J. Sci. 242, 457-77, 542-62 (1944)
H65. Hilpert, R.S., and Schweinhagen, R., Z. phys. chem., 31B, 1-11 (1935)
H66. Hilpert, S., and Lindner, A., Z. phys. chem., 22B, 395-405 (1933)
H67. Hilpert, S., and Nacken, R., Ber. 43, 2565-73 (1910)
H68. Himmel, H., Neues Jahrb. Min., (A), Beil. 64, 67-70 (1931)
H69. Hincke, W.B., J.A.C.S., 52, 3869-77 (1930)
H70. Hoard, J.L., J.A.C.S., 61, 1252-9 (1939)
H71. Hoard, J.L., and Vincent, W.B., J.A.C.S., 61, 2849-52 (1939)
H72. Hoard, J.L., and Vincent, W.B., J.A.C.S., 62, 3126-9 (1940)
H73. Hoeg, F.M.A., Z. Analy. Chem., 81, 114-6 (1930)
H74. Hoenigschmid, O., Z. anorg. allgem. chem., 214, 281-8 (1933)
H75. Hoenigschmid, O., and Birckenbach, L., Ber., 54, 1873-1904 (1921)
H76. Hoenigschmid, O., and Kapfenberger, W., Z. anorg. allgem. chem. 212, 198-208 (1933)
H77. Hoenigschmid, O., and Sachtleben, R., Z. anorg. allgem. chem., 191, 309-17 (1930)
H78. Hoenigschmid, O., and Sachtleben, R., Z. anorg. allgem. chem., 195, 207-27 (1931)
H79. Hoenigschmid, O., and Striebel, H., Z. anorg. allgem. chem., 212, 385-92 (1933)
H80. Hoerman, F., Z. anorg. allgem. chem., 177, 145-86 (1929)
H81. Hoermann, G., Dissert. Evlangen, 1879
H82. Hoffmann, A., Z. physik. chem., B28, 65-77 (1935)
H83. Hoffmann, A., Naturwiss., 26, 431 (1938)
H84. Hoffmann, G.F., and Lenher, V., J.A.C.S., 51, 3177-84 (1929)
H85. Hofmann-Degen, Sitz.-Ber. Heidelb, Akad., 1919, A, No. 14
H86. Holden, R.B., Speiser, R., and Johnston, H.L., J.A.C.S. 70, 3896 (1948)
H87. Holgersson, S., and Herrlin, A., Z. anorg. allgem. chem., 198, 69-78 (1931)
H88. Holgersson, S., and Karlson, A., Z. anorg. allgem. chem., 183, 384-94 (1929)
H89. Horan, H.A. and Damiano, J.B., J.A.C.S., 57, 2434-6 (1935)
H90. Hostetter, J.C., and Roberts, H.S., J. Am. Ceram. Soc., 4, 927-38 (1921)
H91. Huelsmann, O. and Biltz, W., Z. anorg. allgem. chem., 219, 357-66 (1934)
H92. Huelsmann, O., Biltz, W., and Meisel, K., Z. anorg. allgem., chem., 224, 73-83 (1935)
H93. Huettig, G.F., and Klapholz, B., Z. anorg. allgem. chem., 207, 225-33 (1932)

H94. Huettig, G.F., and Mytyzek, R., Z. anorg. allgem. chem., 190, 353-63 (1930)

H95. Huettig, G.F., and Toischer, K., Z. anorg. allgem. chem., 207, 273-88 (1932)

H96. Hugill, W., Iron Steel Inst. (London), Special Repts., No. 26, 201-4 (1940)

H97. Hultgren, R., Gingrich, N.S., and Warren, B.E., J. Chem. Phys., 3, 351-5 (1935)

H98. Hume, J., J. Chem. Soc., 127, 1036-9 (1925)

H99. Hurblut, C.S., and Taylor, R.E., Am. Mineral. 22, 1052-1057 (1937)

H100. Hutchison, C.A., and Johnston, H.L., J.A.C.S., 62, 3165-8 (1940)

H101. Hutchison, D.A., Phys. Rev. 66, 144 (1944)

H102. Hutchison, D.A., J. Chem. Phys. 13, 383 (1945)

H103. Huttenlocker, H.F., Z. Krist., 90, 508-16 (1935)

H104. Huttner, K., and Knappe, S., Z. anorg. allgem. chem., 190, 27-47 (1930)

I 1. Ide, K.H., Z. anorg. allgem. chem., 235, 311 (1938)

I 2. Iijima, S., Bull. Inst. Phys. Chem. Research (Japan) 21, 737-43 (1942)

I 3. Ikornikooa, N.Y. and Godlevskii, M.N., Compt. rend. acad. sci. U.R.S.S. 33, 257-8 (1941) (in English)

I 4. Iley, R. and Riley, H.L., Nature 160, 468 (1947)

I 5. Ingerson, E. and Morey, G.W., Am. Mineral., 28, 448-55 (1943)

I 6. Ingerson, E., Morey, G.W. and Tuttle, O.F., Am. Jour. Sci. 246, 31 (1948)

I 7. Inghram, M.G., Hess, D.C. Jr. and Hayden, R.J., Phys. Rev. 72, 1269 (1947)

I7a. Insley, H. and Glaze, F.W., Bur. Standards, J. Research, 12 471-4 (1934)

I 8. International Critical Tables of Numerical Data, Physics, Chemistry and Technology, 7 volumes plus an index, McGraw-Hill Book Co., New York. 1926-1933

I8a. International Temperature Scale, Eg., Am. J. Physics, 17, 326 (1949)

I 9. Inuzuka, H., Mazda Kenkyn Jiho, 15, 305-9 (1940)

I10. Ipatiew, W., and Nikolajew, W., Ber., 61, 630-4 (1928)

I11. Irmann, F., Helv. Chim. Acta, 31, 1584, 2263 (1948)

I12. Ishikawa, F., and Abe, H., Sci. Papers Inst. Phys. Chem. Research, (Tokyo), 34, 775-86 (1938)

I13. Iskoldskii, I.I., Chem. Abs., 26, 4004 (1932)

I14. Ivanov, L.L., Vernadsky Jubilee Vol., Acad. Sci., U.S.S.R., 2 789-93 (1936)

I15. Ivanov-Emin, B.N., J. Gen. Chem. (U.S.S.R.), 10, 1813-8 (1940)

I16. Ivanov-Emin, B.N., J. Gen. Chem. (U.S.S.R.), 17, 430 (1947)

I17. Ivanov-Emin, B.N. and Rabovik, Y.I., J. Gen. Chem. (U.S.S.R.) 17, 1061-9 (1947) (in Russian)

I18. Ivanov-Emin, B.N. and Rabovik, Y.I., J. Gen. Chem. (U.S.S.R.) 17, 1247 (1947)

I19. Iwase, E. and Saito, N., Sci. Papers Inst. Phys. Chem. Research (Tokyo) 39, 300-4 (1942)

I20. Iwase, K., and Fukusima, M., Sci. Rept., Tohoku Imp. Univ., Ser. 1, 21, 114-26 (1932)

J 1. Jablczyinski, K., and Wieckowski, W., Z. anorg. allgem. chem., 152, 207-12 (1926)
J 2. Jaeger, F.M., Z. anorg. allgem. chem., 101, 1-214 (1917)
J 3. Jaeger, F.M. and Germs, H.C., Z. anorg. allgem. chem., 119, 145-73 (1921)
J 4. Jaeger, F.M., and Klooster, H.S. v., Z. anorg. allgem. chem., 78, 245-68 (1912)
J 5. Jaeger, F.M., and Klooster, S.v., Akad. Amsterdam Versl., 22, 905 (1913/1914)
J 6. Jaeger, F.M., and Klooster, S.v., Proc. Akad. Wet. Amsterdam, 16, 857 (1914); 17, 239 (1914)
J 7. Jaeger, F.M., and Klooster, S.v., Proc. Akad. Wet. Amst., 18, 896 (1915)
J 8. Jaeger, F.M., and Klooster, S.v., Akad. Amsterdam Versl. 24, 937 (1915/1916)
J 9. Jaeger, F.M., Proc. Amsterdam, 18, 896 (1916)
J10. Jaeger, F.M., and Klooster, H.S. van, Sprechsaal, 52, 256 (1919)
J11. Jaeger, F.M., and Simek, A., Akad. Amsterdam Versl., 23, 130-(?) 149 (1914/1915) or Proc. Akad. Wet. Amst., 17, 268 (1914)
J12. Jaencke, E., Z. Phys. Chem., 127, 71-92 (1927)
J13. Jaffe, H.W., Sherwood, A.M., and Peterson, M.J., Am. Mineral. 33, 152-7 (1948)
J14. Jander, W. and Stamm, W., Z. anorg. chem., 207, 289-307 (1932)
J15. Jantsch, G., Grubitsch, H., Hoffmann, F., and Alber, H., Z. anorg. allgem. chem., 185, 49-64 (1929)
J16. Jantsch, G., Jawurek, H., Skalla, N., and Gawalowski, H., Z. anorg. allgem. chem., 207, 353-67 (1932)
J17. Jantsch, G., and Ohl, A., Ber., 44, 1274-80 (1911)
J18. Jantsch, G., Skalla, N., and Grubitsch, H., Z. anorg. allgem. chem., 212, 65-83 (1933)
J19. Jantsch, G., Skalla, N., and Jawurek, H., Z. anorg. allgem. chem., 201, 207-20 (1931)
J20. Jellinek, M.H. and Fankuchen, I., Ind. Eng. Chem., 37, 158 (1945)
J21. Jenckel, E., Z. anorg. allgem. chem., 227, 214-20 (1936)
J22. Jimori, S., Z. anorg. allgem. chem., 167, 145-72 (1927)
J23. Jimori, S., and Yoshimura, Sci. pap. Inst. phys. chem. Res., Tokio, 10, 224 (1929)
J24. Johns, H.E., and Wilhelm, J.O., Can. J. Res., A 15, 101-8 (1937)
J25. Johnston, H.L., J.A.C.S., 61, 878-80 (1939)
J26. Johnston, H.L., and Long, E.A., J.A.C.S., 56, 31-5 (1934)
J27. Johnston, J., Z. phys. chem., 62, 330-58 (1908)
J28. Johnston, J., and Adams, L.H., J.A.C.S., 34, 563-84 (1912)
J29. Johnston, J., Merwin, H.E., and Williamson, E.D., Am. J. Sci., (4), 41, 473-512 (1916)
J30. Jolibois, P., Compt. rend. 224, 1395-6 (1947)
J31. Jolliffe, F., Am. Mineral., 20, 405-25 (1935)

J32. Joly, A., and Dufet, H., Compt. rend., 102, 1391-4 (1886)
J33. Joly, J., Phil. Mag., (6), 25, 301-11, 856-69 (1913)
J34. Joly, J., Phil. Mag., (6), 27, 1-14 (1914)
J35. Jones, T.O., M.D.D.C. 1630
J36. Jong, W.F., and Stek, H., Z. Krist., 83, 496 (1932)
J37. Jong, W.F., and Willems, H.W.V., Physica, 7, 74 (1927)
J38. Jong, W.F., and Willems, H.W.V., Z. anorg. allgem. chem., 170, 241-5 (1928)
J39. Jorissen, W.P., Bassett, H., Damiens, A., Fichter, F., and Remy, H., J.A.C.S., 63, 889-97 (1941)
J40. Junker, E., Z. anorg. allgem. chem., 228, 97-111 (1936)
J41. Juza, R., and Biltz, W., Z. Elektrochem., 37, 498 (1931)
J42. Juza, R., Biltz, W., and Meisel, K., Z. anorg. allgem. chem., 205, 273-86 (1932)
J43. Juza, R., Huelsmann, O., Meisel, K., and Biltz, W., Z. anorg. allgem. chem., 225, 369-85 (1935)
J44. Juza, R., and Meyer, W., Z. anorg. allgem. chem., 213, 273-82 (1933)

K 1. Kalinin, P.V., Mem. Soc. Russe Mineral. 74, No. 1, 62-5 (1945) (in Russian)
K 2. Kalyuzhnyi, V.A., Doklady Akad. Nauk S.S.R. 59, 1631-3 (1948)
K 3. Kamayama, N. and Fukumoto, T., J. Soc. Chem. Ind. Japan 49, 155-7 (1946)
K 4. Kammermeyer, K., and Peck, A.B., J. Am. Ceram. Soc., 16, 363-6 (1933)
K 5. Kaspar, J.V., Rozpraviy Ceske Akad. 51, No. 14, 8 pp. (1941); Mineralog. Abstracts 9, 186 (1946)
K 6. Kaspar, J.V., Chem. Listy 36, 78-81 (1942); Chem. Zentr. 1942, II, 511-12.
K6a. Katz, J.J. and Gruen, D.M., J.A.C.S., 71, 2106 (1949)
K 7. Kauffman, A.J., Jr., Am. Mineral. 28, 512 (1943)
K 8. Kay, H.F., Acta Cryst. 1, 229 (1948)
K 9. Kay, H.F. and Rhodes, R.G., Nature 160, 126-7 (1947)
K10. Keevil, N.B., and Thorvaldson, T., Canad. J. Res., 14B, 20-30 (1936)
K11. Kelley, K.K., J. Chem. Phys., 8, 316-22 (1940)
K12. Kelley, K.K., U.S. Bureau of Mine Bulletin No. 371, 1934
K13. Kelley, K.K., U.S. Bureau of Mine Bulletin No. 383, 1935
K14. Kelley, K.K., U.S. Bureau of Mine Bulletin No. 384, 1935
K15. Kelley, K.K., U.S. Bureau of Mine Bulletin No. 393, 1936
K16. Kelley, K.K., U.S. Bureau of Mine Bulletin,No. 394, 1936
K17. Kelley, K.K., U.S. Bureau of Mine Bulletin No. 406, 1937
K18. Kelley, K.K., U.S. Bureau of Mine Bulletin No. 407, 1937
K19. Kelley, K.K., U.S. Bureau of Mine Bulletin No. 434, 1941
K20. Kendall, J., and Adler, H., J.A.C.S., 43, 1470-81 (1921)
K21. Kendall, J., Crittenden, E.D., and Miller, H.K., J.A.C.S., 45, 963-96 (1923)
K22. Kendall, J., and Davidson, A.W., Ind. Eng. Chem., 13, 303-4 (1921)

K23. Kendall, J., and Landon, M.L., J.A.C.S., 42, 2131-42 (1920)
K24. Keppeler, G., and D'Ans, J., Z. Phys. Chem., 62, 89-118 (1908)
K25. Kerr, P.F. and Holmes, R.J., Bull. Geol. Soc. Am. 56, 479 (1945)
K26. Kerr, P.F. and Young, F., Am. Mineral. 29, 192-210 (1944)
K27. Kerr-Lawson, D.E., Univ. Toronto Studies. Geol. Ser., 20, 63-7 (1925)
K28. Ketelaar, J.A.A., Z. Kryst., 92, 155-6 (1935)
K29. Ketelaar, J.A.A., Chem. Abs., 35, 2392 (1941)
K30. Ketelaar, J.A.A., t'Hart, W.H., Moerel, M., and Polder, D., Z. Kryst., 101, 396-405 (1939)
K31. Ketelaar, J.A.A., and Willems, P.J.H., Rec. trav. chim., 56, 29-35 (1937)
K32. Kiehl, S.J., and Hill, T.M., J.A.C.S., 49, 123-32 (1927)
K33. King, F.E., and Partington, J.R., J. Chem. Soc., (London), 129, 925-9 (1926)
K34. King, E.G., Torgeson, D.R. and Cook, O.A., J.A.C.S. 70, 2160-3 (1948)
K35. Kitaigorodskii, I.I., Popova, T.A., and Botvinkin, O.K., J. Phys. Chem., (U.S.S.R.), 4, 380-2 (1933)
K36. Klein, A., Ann. chim., 14, 263-317 (1940)
K37. Kleinheksel, J.H., and Kremers, H.C., J.A.C.S., 50, 959-67 (1928)
K38. Klemenc, A., and Bankowski, O., Z. anorg. allgem. chem., 208, 348-66 (1932)
K39. Klement, R., Z. anorg. allgem. chem., 164, 195-201 (1927)
K40. Klement, R., Z. anorg. allgem. chem., 228, 232-40 (1936)
K41. Klement, R., and Uffelmann, R., Naturwissenschaften, 29, 300-1 (1941); Chem. Abs., 36, 696 (1942)
K42. Klemm, W., Z. anorg. allgem. chem., 152, 235-51 (1926)
K43. Klemm, W., and Biltz, W., Z. anorg. allgem. chem., 152, 225-34 (1926)
K44. Klemm, W., and Dierks, F., Z. anorg. allgem. chem., 219, 42-4 (1934)
K45. Klemm, W., and Frischmuth, G., Z. anorg. allgem., 218, 249-51 (1934)
K46. Klemm, W., and Henkel, P., Z. anorg. allgem. chem., 207, 73-86 (1932)
K47. Klemm, W., and Henkel, P., Z. anorg. allgem. chem., 220, 180-2 (1934)
K48. Klemm, W., and Koczy, A., Z. anorg. allgem. chem., 233, 84-96 (1937)
K49. Klemm, W., Meisel, K., and Vogel, H.U.V., Z. anorg. allgem. chem., 190, 123-44 (1930)
K50. Klemm, W., and Rockstroh, J., Z. anorg. allgem. chem., 163, 253-6 (1927)
K51. Klemm, W., and Rockstroh, J., Z. anorg. allgem. chem., 176, 181-99 (1928)
K52. Klemm, W., and Schueth, W., Z. anorg. allgem. chem., 184, 352-8 (1929)

K53. Klemm, W., and Tilk, W., Z. anorg. allgem. chem., 207, 161-74 (1932)
K54. Klemm, W., Tilk, W., and Muellenheim, S.v., Z. anorg. allgem. chem., 176, 1-22 (1928)
K55. Klemm, W., and Vogel, H.U.v., Z. anorg. allgem. chem., 219, 45-64 (1934)
K56. Klinkenberg, L.J., Rec. Trav. Chim. Pays-Bas 56, 36 (1937)
K57. Klug, H.P., and Johnson, W.W., J.A.C.S., 59, 2061-3 (1937)
K58. Klug, H.P., and Sears, G.W., J.A.C.S. 67, 878 (1945)
K59. Knick, R., and Kohlmeyer, E.J., Z. anorg. allgem. chem., 244, 67-84 (1940)
K60. Koenigsberger, J., and Mueller, W.J., Neues Jahrb. Min. Pet. Geol., 44, 402 (1921)
K61. Koenigsberger, J., and Schilling, K., Ann. Phys., 32, 179-230 (1910)
K62. Koerber, F., Ann. Phys., (4), 37, 1014-45 (1912)
K63. Kohlmeyer, E.J., Metall u. Erz., 33, 401-13 (1936)
K63a Kohlmeyer, E.J. and Spandau, H., Z. anorg. chem., 253, 37 (1945
K64. Kohlschuetter, H.W., Z. anorg. allgem. chem., 213, 189-205 (1933)
K65. Kolobova, K.K., J. Appl. Chem., (U.S.S.R.) 14, 928 (1941)
K66. Kolthoff, I.M., and Lingane, J.J., J.A.C.S., 57, 2126-31 (1935)
K67. Komandin, A.V., and Tarasenkov, D.N., J. Gen. Chem., (U.S.S.R.) 10, 1333-42 (1940)
K68. Kordes, E., Z. Krist., 91, 193-228 (1935)
K69. Kordes, E., Z. anorg. allgem. chem., 241, 1-38 (1939)
K70. Kordes, E., Z. Phys. Chem., 43B, 173-90 (1939)
K71. Kotov, V.P., J. Phys. Chem., (U.S.S.R.), 13, 829-34 (1939)
K72. Kracek, F.C., J. Phys. Chem., 33, 1281-1303 (1929)
K73. Kracek, F.C., J. Phys. Chem., 34, 1583-98 (1930)
K74. Kracek, F.C., J. Phys. Chem., 34, 2641-50 (1930)
K75. Kracek, F.C., J. Washington Acad. Sci., 26, 307-13 (1936)
K76. Kracek, F.C., J.A.C.S., 61, 2157-61 (1939)
K77. Kracek, F.C., J.A.C.S., 61, 2863-77 (1939)
K78. Kracek, F.C., J.A.C.S., 63, 1989-90 (1941)
K79. Kracek, F.C., Handbook of Phys. Constants, Geol. Soc. America Special Papers, No. 36, 140-174, Jan. 31, 1942
K80. Kracek, F.C., Trans. Am. Geophys. Union 27, 364 (1946)
K81. Kracek, F.C., Bowen, N.L., and Morey, G.W., J. Phys. Chem., 33, 1857-79 (1929)
K82. Kracek, F.C., Bowen, N.L., and Morey, G.W., J. Phys. Chem., 41, 1183-93 (1937)
K83. Kracek, F.C., and Gibson, R.E., J. Phys. Chem., 33, 1304-8 (1929)
K84. Kracek, F.C., and Ksanda, C.J., Trans. Amer. Geophys. Union, 1940, 363
K85. Kracek, F.C., Morey, G.W., and Merwin, H.E., Am. J. Sci., (5), 35A, 143-71 (1938)
K86. Krakan, K.A., Ann. secteur anal. phys-chim. Inst. chim. gin. (U.S.S.R.), 8, 331-50 (1936)

K 87. Krakau, K.A., Mukhin, E.J., and Heinrich, M.S., Compt. rend. acad. sci., U.R.S.S., 14, 281-5 (1937)
K 88. Kratochvil, Fr., Neues Jahrb. Mineral Geol., Ref. I, 1937, 209-10
K 89. Kraus, C.A., and Burgess, W.M., J.A.C.S., 49, 1226-35 (1927)
K 90. Krause, E. and Grosse, A. von, Die Chemie der metall-organischen Verbindungen. Berlin, 1937.
K 91. Krauss, F., Fricke, A., and Querengaesser, H., Z. anorg. allgem. chem, 181, 38-54 (1929)
K 92. Krauss, F., and Gramss, R., Keram. Rundschau, 43, 192-4 (1935)
K 93. Krauss, F., and Schrader, G., Z. anorg. allgem. chem., 176, 385-97 (1928)
K 94. Krauss, F., and Schriever, W., Z. anorg. allgem. chem., 188, 259-73 (1930)
K 95. Kremers, H.C., J. Optical Soc. Am. 37, 337-41 (1947)
K 96. Krenner, J., Z. Kryst. 53, 66 (1914)
K 97. Krings, W., Z. anorg. allgem. chem., 181, 309-36 (1929)
K 98. Kroger, C., Illner, K.W., and Glaeser, W., Z. anorg. allgem. chem., 251, 271 (1943)
K 99. Kruell, F., Z. anorg. allgem. chem., 208, 135-44 (1932)
K100. Kruess, G., and Ohnmais, K., Ber., 23, 2547-52 (1890)
K101. Kruis, A., and Clusius, K., Z. Phys. Chem., 38B, 156-76 (1937)
K102. Krustinsons, J., Z. Elektrochem., 39, 936-9 (1933)
K103. Krustinsons, J., Z. Elektrochem., 43, 65-6 (1937)
K104. Krustinsons, J., Z. Elektrochem., 45, 83 (1939)
K105. Ksanda, C.J., Am. J. Sci., (5), 22, 131-8 (1931)
K106. Ksanda, C.J., and Merwin, H.E., Am. Mineral., 18, 341-4 (1933)
K107. Kurnakova, A.G., Doklady Akad. Nauk. S.S.S.R., 50, 241 (1945). C.A. 43, 2128 (1949)

L 1. Lacroix, A., Compt. rend., 155, 672-7 (1912)
L 2. Laffitte, P., and Grandadam, P., Compt. rend., 198, 1925-7 (1934)
L 3. Lagercrantz, A. and Sillen, L.G., Arkiv Kemi, Mineral. Geol. 25A, No. 20, 21 pp. (1948) (in English)
L 4. Lagerqvist, K., Wallmark, S., and Westgren, A., Z. anorg. allgem. chem., 234, 1-16 (1937)
L 5. Lai, C.F., and Silverman, A., J. Am. Ceram. Soc., 11, 535-41 (1928)
L 6. Lai, C.F., and Silverman, A., J. Am. Ceram. Soc., 13, 393-8 (1930)
L 7. Lamy, A., Ann. chim. Phys., (3), 67, 385-417 (1863)
L 8. Landes, K.K., Am. Mineral., 10, 355-411 (1925)
L 9. Landolt-Boernstein Physika-Lisch-Chemische Tabellen, Julius Springer, Berlin, 5th Ed., edited by W.A. Roth and K. Scheel 2 volumes, 1923.
L 10. Landolt-Boernstein, 5th Ed., 1st. suppl., 1 volume, 1927.
L 11. Landolt-Boernstein, 5th Ed., 2nd. suppl., 2 volumes, 1931.
L 12. Landolt-Boernstein, 5th Ed., 3rd. suppl., 3 volumes, 1935-1936
L 13. Lange, W., and Askitopoulos, K., Z. anorg. allgem. chem., 223, 369-81 (1935)

L14. Lange, W., and Mueller, E., Ber., 63, 1058-70 (1930)
L15. Lapitskii, A.V., J. Gen. Chem. (U.S.S.R.) 16, 917-22 (1946)
L16. Larsen, E.S., Am. J. Sci., (4), 28, 263-74 (1909)
L17. Larsen, E.S., Bauer, L.H., and Berman, H., Am. Mineral., 13, 349-53 (1928)
L18. Larsen, E.S., and Berman, H., U.S. Geological Survey Bull. No. 848, (1934)
L19. Larsen, E.S., and Glenn, M.L., Am. J. Sci., (4), 50, 225-33 (1920)
L20. Larsen, E.S., and Hunter, J.F., J. Washington Acad., 4, 473-79 (1914)
L21. Larsen, E.S., and Montgomery, A., Am. Mineral., 25, 513-8 (1940)
L22. Larsen, E.S., and Shannon, E.V., Am. Mineral., 15, 307-37 (1930)
L23. Larsen, H.W.E., Ind. Eng. Chem., Analy. Ed., I, 401-6 (1935)
L24. Lashchenko, P.N., and Kompanskii, D.I., J. Applied Chem. (U.S.S.R.), 8, 628-52 (1935)
L25. Laubengayer, A.W. and Condike, G.F., J. Am. Chem. Soc. 70, 2274-6 (1948); cf. C.A. 39, 1365
L26. Laubengayer, A.W., and Engle, H.R., J.A.C.S., 61, 1210-14 (1939)
L27. Laubengayer, A.W., Hurd, D.T., Newkirk, A.E., and Hoard, J.L., J.A.C.S. 65, 1924 (1943)
L28. Laubengayer, A.W., and Morton, D.S., J.A.C.S., 54, 2303-20 (1932)
L29. Laubengayer, A.W., and Schirmer, F.B., J.A.C.S., 62, 1578-83 (1940)
L30. Laubengayer, A.W., and Tabern, D.L., J. Phys. Chem. 30, 1047-8 (1926)
L31. Laurie, A.P., McLintock, W.F.P., and Miles, F.D., Proc. Roy. Soc., 89, 418-29 (1914)
L32. Lauro, C., Atti. accad. Italia, Rend. classe sci. fis., mat. nat. (7), 3, 146-50 (1941); Chem. Zentr. 1943, I, 1252
L33. Lea, F.M., and Parker, T.W., Phil. Trans. Roy. Soc., (London), 234, (A), 1-42 (1934)
L34. Lebeau, P., Compt. rend., 126 1418-21 (1898); Ann. Chim. Phys. (7), 16, 488 (457-503) (1899)
L35. LeBlanc, M., and Moebins, E., Z. Elektrochem., 40, 44-6 (1934)
L36. LeBoucher, L.L., Fischer, W., and Biltz, W., Z. anorg. allgem. chem., 207, 61-72 (1932)
L37. LeCoultre, F.C.F., Bull. Soc. Min. France, 33, 429 (1923)
L38. Lehrman, A., and Breslow, D., J.A.C.S., 60, 873-6 (1938)
L39. Lehrman, A., Selditch, H., and Skell, P., J.A.C.S., 58, 1612-5 (1936)
L40. Lemarchands, M., and Jacob, M., Bull. soc. chim., (5), 2, 479-87 (1935)
L41. Leverenz, H.W. and Seitz, F., J. Appl. Phys. 10, 479 (1939)
L42. Levi, G.R., Gazz. Chim. Ital., 58, 417-8 (1928)
L43. Levi, G.R., and Fontana, C., Gazz. Chim. ital., 56, 388-96 (1926)
L44. Levi, G.R., and Peyronel, G., Z. Kryst., 92, 190-209 (1935)
L45. Levin, E.M., and McMurdie, H.F., J. Am. Ceram. Soc., 32 (3) 99-105 (1949)

L46. Lewis, G.N., and McDonald, R.T., J.A.C.S., 55, 3057-9 (1933)
L47. Lewis, G.N., and Schutz, P.W., J.A.C.S., 56, 1002 (1934)
L48. Liebhafsky, H.A., Rochow, E.G., and Winslow, A.F., J.A.C.S., 61, 969-70 (1939)
L49. Liempt, J.A.M., Z. anorg. allgem. chem., 143, 285-92 (1925)
L50. Linck, G., and Jung, H., Z. anorg. allgem. chem., 137, 407-17 (1924)
L51. Linhard, M., Z. anorg. allgem. chem., 236, 200-8 (1938)
L52. Lipscomb, W.N. and Whittaker, A.G., J.A.S.A. 67, 2019 (1945)
L53. Little, G., Lieb. Ann., 112, 212 (1859)
L54. Littmann, H., Physik Z., 41, 468-75 (1940)
L55. Long, L.H., J. Chem. Phys. 16, 1087 (1948); cf. C.A. 41, 1542 g.
L56. Lorenz. R., and Herz, W., Z. anorg. allgem. chem., 117, 103-10 (1921)
L57. Loria, St., Proc. Amsterdam, 14, 972 (1912)
L58. Loria, St. and Zakrzewski, C., Krakauer Anz. (A), 278-86 (1910)
L59. Loriers, J., Compt. rend. 226, 1018-19 (1948)
L60. Luedke, W., Fortschr. Min., 18, 30 (1934)
L61. Lundell, G.E.F., and Hoffman, J.I., Bur. Stand. J. Res., 15, 409-20 (1935)
L62. Lundqvist, D., Arkiv Kemi, Mineral. Geol. 24A, No. 21, 12pp. (1947)(in English)
L63. Lutin, Jr., D.B., Phys. Rev., (2), 45, 161-5 (1934)

M 1. Machatschki, F., Z. Krist., 72, 541-2 (1930)
M 2. Machatschki, F., and Moser, A., Naturwissenschaften, 24, 743 (1936)
M 3. Maekawa, G., J. Soc. Chem. Ind. Japan 45, 751-3 (1942)
M 4. Magnusson, L.B. and LaChapelle, T.J., J.A.C.S. 70, 3534 (1948)
M 5. Maier, C.G., U.S. Bur. Mines, Rpt. of Investigations, No. 3262, 54 pp. (1934)
M 6. Maier, C.G., and Hincke, W.B., Am. Inst. Mining Met. Eng., Tell. Bull., No. 449 (1932)
M 7. Makarov., S.Z., and Shul'gma, Bull. acad. sci., U.S.S.R., Classe sci. chim., 1940, 691-700
M 8. Mallard, E., Bull. Soc. Min. 15, 18, (1892)
M 9. Marchal, G., Compt. rend., 175, 270-2 (1922)
M10. Marchal, G., J. Chim. phys., 22, 572 (1925)
M11. Marsh, J.K., J. Chem. Soc., (London), 138, 772-3 1935
M12. Martin, E., and Vogel, R., Arch. Eisenhüttenw., 8, 249-54 (1934/1935)
M13. Mason, B., Geol. Fören Förh., 63, 262 (1941)
M14. Mathewson, C.H., J.A.C.S., 29, 867-80 (1907)
M15. Matignon, C., and Passillé, A. de, Compt. rend., 198, 777-9 (1934)
M16. Matsui, M., Kiyoura, R., and Iwanaga, E., J. Soc. Chem. Ind., Japan, Supp. Binding, 41, 123-5 (1938)
M17. McCoy, H.N., J.A.C.S., 59, 1131-2 (1937)
M18. McCullough, J.D., Brewer, L. and Bromley, L.A., Acta Cryst. 1, 287-290 (1948)
M19. McIntosh, A.B., Rait, J.R., and Hay, R., J. Roy. Tech. Coll., 4, 72-6 (1937)

M20. McMurdie, H.F., Bur. Stand. J. Res., 26, 489-94 (1941)

M21. McMurdie, H.F., and Bunting, E.N., Bur. Stand. J. Res., 23, 543-47 (1939)

M22. Megaw, H.D., Nature 155, 484 (1945)

M23. Megaw, H.D., Experientia 2, 183 (1946)

M24. Megaw, H.D., and Simon, F., Nature, 138, 244 (1936)

M25. Meisel, K., Z. anorg. allgem. chem., 207, 121-8 (1932)

M26. Meisel, K., Z. anorg. allgem. chem., 219, 141-2 (1934)

M27. Meissner, F., Z. anorg. allgem. chem., 110, 187-95 (1920)

M28. Melkov, V.G., Mem. Soc. Russe Mineral. 74, No. 1, 41-7 (1945) (in Russian)

M29. Mellor, J.W., Comprehensive Treatise on Inorganic and Theoretical Chemistry, 16 volumes, Longmans, Green and Co., New York. 1922-1937

M30. Melon, J., Chem. Abs., 29, 7875 (1935)

M31. Melon, J., Ann. soc. geol. Belg. Bull. 66, 53-6 (1943); Chem. Zentr. 1943, II, 995.

M32. Melon, J. and Dallemagne, M.J., Ann. soc. geol. Belg. Bull. 69, Nos. 1,2,3,B19 (1945-1946)

M33. Menzel, H., Bruckner, A. and Schulz. H., Z. Elektrochem., 36, 188 (1930)

M34. Menzel, H. and Schulz, H., Z. anorg. allgem. chem., 245, 157-220 (1940)

M35. Menzel, H. and Schulz, H., Z. anorg. allgem. chem., 251, 167 (1943)

M36. Menzel, H., Schulz, H., Sieg, L., and Voigt, M., Z. anorg. allgem. chem., 224, 1-22 (1935)

M37. Menzel, W., and Mohry, F., Z. anorg. allgem. chem., 210, 257-63 (1933)

M38. Menzer, G., Z. Krist., 69, 301-96 (1928/29)

M39. Menzer, G., Z. Krist., 106, 34-49 (1945)

M40. Merwin, H.E., J. Washington Acad. Sci., 1, 59 (1911)

M41. Merwin, H.E., Proc. Am. Soc. Test. Mat., 17, (2), 496-526 (1917)

M42. Merwin, H.E., Private communication, dated Feb. 10, 1942.

M43. Merz, A.R., J.A.C.S., 49, 1511-2 (1927)

M44. Messerknecht, C. and Biltz, W., Z. anorg. allgem. chem., 148, 155 (1925)

M45. Meyer, G., and Heck, A., Z. phys. chem., 100, 316-33 (1922)

M46. Meyer, J. and Holowatyj, M., Chem. Ber. 81, 119-23 (1948)

M47. Meyer, R.J., and Hoetgers, K., Z. anorg. allgem. chem., 57, 104-12 (1908)

M48. Meyer, St., Z. phys. chem., 37, 237 (1901)

M49. Meyers, E.L., and Hopkin, B.S., J.A.C.S., 57, 241-3 (1935)

M50. Michel, Z. Krist., 53, 538 (1914)

M51. Michener, C.E. and Peacock, M.A., Am. Mineral. 28, 343-55 (1943)

M52. Miller, J.J., Z. Krist., 94, 131-6 (1936)

M53. Miller, J.J., Z. Krist., 99, 32-7 (1938)

M54. Milton, C., Murata, K.J. and Knechtel, M.M., Am. Mineral. 29, 92 (1944)

M55. Minder, W., Z. Krist., 96, 15-19 (1937)

M56. Minder, W., Z. Krist. (A) 96, 15-19 (1937)
M57. Misciattelli, P., Gazz. Chim. Ital., 60, 882-5 (1930)
M58. Moles, E., and Crespi, M., Z. Phys. Chem., 130, 337-44 (1927)
M59. Monselise, G.G., Gazz. chim. ital., 67, 748-50 (1937)
M60. Monselise, G.G., Gazz. chim. Ital., 68, 600-1 (1938)
M61. Monselise, G.G., and Scaccabarozzi, G., Gazz. chim. ital., 67, 511-3 (1937)
M62. Montigne, E., Z. anorg. chem. 252, 111-12 (1943)
M63. Montignie, E., Bull. soc. chim., 1946, 276
M64. Montignie, E., Bull. soc. chim. France 1947, 564
M65. Mooney, R.C.L., Acta Cryst. 1, 161-2 (1948)
M66. Mooney, R.C.L., Acta Cryst., 1, 163-5 (1948)
M67. Mooney, R.C.L., J. Chem. Phys. 16, 1003 (1948)
M68. Mooney, R.C.L., Phys. Rev. 72, 1269 (1947); M.D.D.C.-1520 (AEC)
M69. Mooney, R.C.L., Phys. Rev., 73, 653A (1948)
M70. Mooney, R.C.L. and Zachariasen, W.H., A.E.C.D.-1787
M71. Moore, G.E. and Kelley, K.K., J.A.C.S., 69, 2105-7 (1947)
M72. Morette, A., Compt. rend. 215, No. 3, 86-8 (1942)
M73. Morette, A., Compt. rend. 216, 566-8 (1943)
M74. Morey, G.W., J.A.C.S., 36, 215-30 (1914)
M75. Morey, G.W., J.A.C.S., 39, 1173-1229 (1917)
M76. Morey, G.W., Bull. Am. Ceram. Soc., 13, 79-80 (1934)
M77. Morey, G.W., Properties of Glass, A.C.S. Monograph Series No.77 Reinhold Publishing Corp., New York, N.Y. 1938.
M78. Morey, G.W., Private Communications (1946).
M79. Morey, G.W., and Bowen, N.L., J. Phys. Chem., 28, 1167-79 (1924)
M80. Morey, G.W., and Bowen, N.L., J. Soc. Glass Tech., 9, 226-64 (1925)
M81. Morey, G.W., and Burlew, J.S., Am. J. Sci., (5), 35A, 185-215 (1938)
M82. Morey, G.W., and Ingerson, E., Economic Geology, 32, Suppl., 607-61 (1937)
M83. Morey, G.W. and Ingerson, E., Am. J. Sci. 242, 1-6 (1944)
M84. Morey, G.W., Kracek, F.C., and Bowen, N.L., J. Soc. Glass Tech. 14, 149-87 (1930) also, ibid., 15, 57-8 (1931)
M85. Morey, G.W., and Merwin, H.E., J.A.C.S., 58, 2248-54 (1936)
M86. Morozov, A.N., Chem. Abs., 13 (12), 21-8 (1938)
M87. Morris, L.D., and Scholes, S.R., J. Am. Ceram. Soc., 18, 359-60 (1935)
M88. Mott, W.R., Trans. Am. Electrochem. Soc., 34, 255-95 (1918)
M89. Mountain, E.D., Mineral. Mag., 21, 51-4 (1926)
M90. Mountain, E.D., Mineral. Mag. 24, 59-64 (1935)
M91. Mueller, J.H., J.A.C.S., 43, 1085-95 (1921)
M92. Mueller, W.J., and Koenigsberger, J., Z. anorg. allgem. chem., 104, 1-26 (1918)
M93. Mulert, O., Z. anorg. allgem. chem., 75, 198-240 (1912)
M94. Mylius, C.R.W., Acta. Acad. Aboensis, I, (3), 45 (1933)

N 1. Nacken, R., Neues Jahrb. Min., 24, 1 (1907)
N 2. Nacken, R., and Grünewald, M.E., Zement, 15, 615 (1926)
N 3. Nagelschmidt, G., J. Chem. Soc., 140, 865-7 (1937)

N 4. Narray-Szabo, I., Naturwissenschaften 31, 466 (1943); cf. C.A. 38,9^4

N 5. Narray-Szabo, I. and Sigmond, G., Mat. Termesz. ertes. 60, 364-72 (1941); Neues Jahrb. Mineral., Geol., Ref. I, 1942, 112.

N 6. Natta, G., Gazz. chim. ital., 58, 344-58 (1928)

N 7. Natta, G., and Passerini, L., Gazz. Chim. Ital., 58, 597-618 (1928)

N 8. Natta, G., and Passerini, L., Atti. accad. Lincei. Rend., (6), 9, 557-63 (1929)

N 9. Natta, G., and Passerini, L., Gazz. Chim. Ital., 59, 280-8 (1929)

N10. Natta, G., and Passerini, L., Atti. Accad. Linc. Rend., (6), 14, 38-43 (1931)

N11. Natta, G., and Strada, M., Gazz. Chim. Ital., 58, 419-33 (1928)

N12. Naylor, B.F., J.A.C.S. 67, 2120 (1945)

N13. Naylor, B.F., J. Chem. Phys. 13, 329 (1945)

N14. Naylor, B.F., J.A.C.S. 68, 1077 (1946)

N15. Naylor, B.F. and Cook, O.A., J.A.C.S. 68, 1003 (1946)

N16. Nelson, J.B., and McKee, J.H., Nature 158, 753-4 (1946)

N17. Neumann, B., Kroeger, C., and Juettner, H., Z. Elektrochem. 41, 725-36 (1935)

N18. Neumann, B., and Sonntag, A., Z. Elektrochem., 39, 799-806 (1933)

N19. Neumann, F., Z. anorg. allgem. chem., 145, 193-238 (1925)

N20. Neumann, H., Norsk. Geol. Tids. 21, 19 (1941); Chem. Zentr. 1942, I, 596

N21. Neusser, E., Z. anorg. allgem. chem., 135, 313-26 (1924)

N22. Nicholes, E.L., and Howes, H.L., Carnegie Inst. Public., 298, 207 (1919)

N23. Nielsen, A.H., Z. anorg. allgem. chem., 224, 84 (1935)

N24. Nielsen, A.H., Z. anorg. allgem. chem., 232, 155-60 (1937)

N25. Nielsen, A.H., Z. anorg. allgem. chem., 244, 85-8 (1940)

N26. Nieuwenburg, C.J., van., Rec. Trav. Chim., 48, 402-5 (1929)

N27. Niggli, P., Z. anorg. allgem. chem., 98, 241-326 (1916)

N28. Nikolaev, A.V., and Chelishcheva, A.G., Compt. rend. acad. sci. U.R.S.S., 28, 127-30 (1940)

N29. Nikolaev, N.S., Ivanov, N.A., and Koltypin, S.G., J. Applied Chem., (U.S.S.R.), 9, 1183-90 (1936)

N30. Nishioka, U. and Okamoto, M., Sci. Rept., Tohoku. Imp. Univ., 1st. Ser., 24, 141-9 (1935)

N31. Noddack, J. and W., Z. anorg. allgem. chem., 181, 1-37 (1929)

N32. Nogareda, C., An. Soc. Espan. Fis. Quim., 29 51-61 (1931)

N33. Nogareda, C., An. Soc. Espan. Fis. Quim., 29, 131-45 (1931)

N34. Norton Co., Worcester, Mass., Private Communication, Mar. 13, 1941.

N35. Novosselova, A.V., Levina, M.E., Simanov, Y.P., and Zhasmin. A.G., J. Gen. Chem. (U.S.S.R.) 14, 385, 391 (1944)

N36. Nowacki, W., Z. Kryst., 99, 339-41 (1938)

N37. Nowacki, W., Naturwissenschaften, 26, 463 (1938)

N38. Nowacki, W., Z. Kryst., 101, 273-83 (1939)

N39. Nowacki, W., and Beck, G., Z. Krist., 100, 242-50 (1938)
N40. Nuffield, E.W., Trans. Roy. Soc. Can. 38, IV, 59 (1944)
N41. Nuffield, E.W. and Peacock, M.A., Univ. Toronto Studies Geol. Ser. No. 49, 17 (1945)

O 1. O'Daniel, H., Z. Krist., 86, 192-202 (1933)
O 2. O'Daniel, H., and Tscheischwili, L., Z. Krist., 103, 178-85 (1941)
O 3. O'Daniel, H., and Tscheischwili, L., Z. Krist., 104, 348-57 (1942); cf. C.A. 36, 6863^7
O 4. O'Daniel, H., and Tscheischwili, L., Z. Krist., 105, 273 (1944)
O 5. Oddo, G., Gazz. chim. ital., 31, II, 158-70 (1901)
O 6. Oftedal, I., Z. Phys. Chem., 134, 301-10 (1928)
O 7. Oftedal, I., Z. Phys. Chem., B5, 272-91 (1929)
O 8. Okada, I., Bull. Shanghai Sci. Inst., 1, 129-48 (1937)
O 9. Okuno, T., Mem. Faculty Eng. Kyusku Imp. Univ., 7, 275-355 (1935)
O10. Osborn, E.F., Am. Jour. Sci. 240, 781 (1942)
O11. Osborn, E.F., J. Am. Ceram. Soc. 26, 321-32 (1943)
O12. Osborn, E.F. and Schairer, J.F., Am. J. Sci., 239, 715-63 (1941)
O13. Osterberg, H., Phys. Rev., 49, 552-3 (1936)
O14. Otin, C.N., Bull. Sci. Acad. Roumaine, 1, 189-96 1912/1913. Some of the bismuth silicates may not be true compounds.
O15. Ouvrard, L., Ann. Chim. Phys., (6), 16, 289-347 (1889)

P 1. Pabst, A., Am. Mineral., 15, 69-73 (1930)
P 2. Pabst, A., Am. J. Sci., (5), 26, 72-9 (1933)
P 3. Pabst, A., Am. Mineral., 22, 861-8 (1937)
P 4. Pabst, A., Am. Mineral., 28, 372-90 (1943)
P 5. Pabst, A., J. Chem. Phys. 11, 145 (1943)
P 6. Palache, C., Bauer, L.H., and Berman, H., Am. Mineral., 13, 142-4 (1928)
P 7. Palm, A., J. Phys. & Colloid Chem. 52, 959-61 (1948)
P 8. Paris, R., and M.-Monval, P., Compt. rend., 202, 2075-7 (1936)
P 9. Parker, T.W. and Nurse, R.W., J. Iron Steel Inst. (London), Advance Copy, May, 1943, 12 pp.
P10. Parravano, N., and Caglioti, V., Gazz. Chim. Ital., 60, 923-33 (1930)
P11. Parravano, N., and Montoro, V., Atti. Accad. Linc., (6), 7, 885, (1928)
P12. Partridge, E.P., Hicks, V., and Smith, G.W., J.A.C.S., 63, 454-66 (1941)
P13. Pascal, P., Traite de chimie minerale, 12 volumes, Masson et Cie, Paris. 1931-1934
P14. Pascal, P., and Minne, P., Compt. rend., 193, 1303-5 (1931)
P15. Passerini, L., Gazz. chim. ital., 60, 389-99 (1930)
P16. Passerini, L., Gazz. chim. ital., 60, 758-61 (1930)
P17. Passerini, L., Gazz. Chim. Ital., 60, 762-76 (1930)
P18. Passerini, L., and Baccaredda, M., Atti. accad. Lincei., 14, 33-7 (1931)

P19. Patnode, W.I., and Papish, J., J. phys. chem., 34, 1494-6 (1930)

P20. Patry, M., Bull. Soc. Chim., (5), 3, 845-60 (1936)

P21. Pauling, L., J.A.C.S., 59, 1132-3 (1937)

P22. Pauling, L., and Dickinson, R.G., J.A.C.S., 46, 1615-22 (1924)

P23. Pauling, L., Klug, H.P., and Winchell, A.N., Am. Mineral., 20, 492-501 (1935)

P24. Peacock, M.A., Am. J. Sci., 30, 495-529 (1935)

P25. Peacock, M.A., Trans. Roy. Soc. Can. IV, 36, 107-18 (1942)

P26. Peacock, M.A., Univ. Toronto Studies, Geol. Ser. No. 47, 63-9 (1942); cf. C.A. 36, 1871

P27. Peacock, M.A., Univ. Toronto Studies, Geol. Ser. 50, 81 (1946)

P28. Peacock, M.A., and Berry, L.G., Univ. Toronto Studies, Geol. Ser. No. 44, 47-69 (1940)

P29. Peacock, M.A., and Vigfusson, V.A., Univ. Toronto Studies, Geol. Ser., 42, 113-21 (1939)

P30. Pearson, T.G., and Robinson, P.L., J. Chem. Soc. (London), 133, 1473-97 (1930)

P31. Pearson, T.G., and Robinson, P.L., J. Chem. Soc. (London), 134, 413-20 (1931)

P32. Pearson, T.G., and Robinson, P.L., J. Chem. Soc. (London), 136, 1427-9 (1933)

P33. Pehrman, G., Acta Acad. Aboensis, Math. Phys., 10, No. 3, 10pp. (1936)

P34. Pellini, G., and Quereigh, E., Atti. Linc., (5), 19 II, 350 (1910)

P35. Pepinsky, R., Z. Krist., 102, 119-31 (1940)

P36. Petersen, M., J.A.C.S., 63, 2617-20 (1941)

P37. Peyronel, G., Z. Kryst., 94, 311-2 (1936)

P38. Peyronel, G., Gazz. chim. ital., 69, 254-62 (1939)

P39. Peyronel, G., Gazz. chim. ital., 72, 77-93 (1942)

P40. Peyronel, G. and Pacilli, E., Atti. accad. Italia, Rend. Classe Sci. fis. mat. nat. (7), 3, 278-88 (1941); Chem. Zentr. 1943, I, 1457-8

P41. Picon, M., Compt. rend., 184, 98-9 (1927)

P42. Picon, M., Compt. rend., 189, 96-100 (1929)

P43. Picon, M., Compt. rend., 195, 957-9 (1932)

P44. Picon, M., Compt. rend., 196, 2003-6 (1933)

P45. Picon, M., Compt. rend., 197, 1415-7 (1933)

P46. Picon, M. and Cogne, Compt. rend., 193, 595-7 (1931)

P47. Pilipenko, P.P., and Oreshkin, I.I., Chem. Abs., 33. 1239 (1936)

P48. Pincus, A., Jour. Opt. Soc. Am. 35, 92 (1945)

P49. Pinsker, Z.G., Tatarinova, L.I., and Novikova, V.A., Acta. Physicochim. U.R.S.S. 18, 378 (1943)

P50. Pitha, J.J., Smith, A.L. and Ward, R., J.A.C.S. 69, 1870-1 (1947)

P51. Poeschl, V., Z. Kryst. 47, 196 (1910)

P52. Pogorelyi, A.D., J. Phys. Chem. (U.S.S.R.) 22, 731 (1948)

P53. Pohland, E., Z. anorg. allgem. chem., 201, 265-81 (1931)

P54. Porter, M.W., Z. Krist., 75, 288-300 (1930)

P55. Posnjak, E., Am. J. Sci., (5), 19, 67-70 (1930)

P56. Posnjak, E., Am. J. Sci., (5), 35A, 247-72 (1938)

P57. Posnjak, E., Allen, E.T., and Merwin, H.E., Z. anorg. allgem. chem., 94, 95-138 (1916)
P58. Posnjak, E., and Barth, T.F.W., Phys. Rev., (2), 38, 2234-9 (1931)
P59. Posnjak, E., and Barth, T.F.W., Z. Krist., 88, 271-80 (1934)
P60. Posnjak, E., and Merwin, H.E., J. Washington Acad. Sci., 9, 25-30 (1919)
P61. Posnjak, E., and Merwin, H.E., Am. J. Sci., (4), 47, 311-48 (1919)
P62. Posnjak, E., and Merwin, H.E., J.A.C.S., 44, 1965-94 (1922)
P63. Posnjak, E., and Tunell, G., Am. J. Sci., (5), 18, 1-34 (1929)
P64. Posnjak, E., and Wychoff, R.W.G., J. Washington Acad. Sci., 12, 248-51 (1922)
P65. Pough, F.H. and Henderson, E.P., Am. Mineral. 30, 572 (1945)
P66. Pough, F.H. and Henderson, E.P., Mineracao e met, 8, 334,Anais acad. brasil. cienc. 17, 13 (1945)
P67. Pourbaix, M., Bull. soc. chim. Belg. 53, 159 (1944)
P68. Prandtl, W., and Huttner, K., Z. anorg. allgem. chem., 149, 235-62 (1925)
P69. Prideaux, E.B.R., and Cox, C.B., J. Chem. Soc., (London), 131, 1603-7 (1928)
P70. Prideaux, E.B.R., and Webb, K.R., J. Chem. Soc., (London), 140, 1-4 (1937)
P71. Pugh, W., J. Chem. Soc., (London), 133, 2369-73 (1930)
P72. Pulfrich, M., Ber. Deutsch. Keram. Ges., 18, 177-93 (1937)
P73. Pushin, N.A., and Baskow, A.V., Z. anorg. allgem. chem., 81, 347-63 (1913)
P74. Pushin, N.A., and Radoicic, M., Z. anorg. allgem. chem., 233, 41-6 (1937)

Q 1. Quervain, M.de, Helv. Phys. Acta, 17, 509 (1944)
Q 2. Quill, L.L., Z. anorg. allgem. chem., 208, 257-72 (1932)
Q 3. Quill, L.L., and Robey, R.F., J.A.C.S., 59, 1071 (1937)

R 1. Rahlfs, O., and Fischer, W., Z. anorg. allgem. chem., 211, 349-67 (1933)
R 2. Raiteri, L., Atti. Linc., (5), 31, I, 112 (1922)
R 3. Rakusin, M.A., and Arsenjew, A.A., Chem. Ztg., 47, 195 (1923)
R 4. Ramdohr, P., Neues Jahrb. Mineral. Geol., Beil. Bd., 68A, 288-95 (1934)
R 5. Ramsdell, L.S., Am. Mineral., 20, 569-74 (1935)
R 6. Rankin, G.A., Z. anorg. allgem. chem., 92, 213-96 (1915); 93, 327-8 (1915)
R 7. Rankin, G.A. and Merwin, H.E., Am. J. Sci., (4), 301-325 (1918)
R 8. Rankin, G.A., and Wright, F.E., Am. J. Sci., (4), 39, 1-79 (1915)
R 9. Rassow, H., Z. anorg. allgem. chem., 114, 117-50 (1920)
R10. Ray, N.N., Z. anorg. allgem. chem., 201, 289-300 (1931)
R11. Redlich, O., and Loeffler, G., Z. Elektrochem., 36, 716-22 (1930)
R12. References not located.
R13. Reichertz, P.P. and Yost, W.J., J. Chem. Phys. 14, 495 (1946)

R14. Reinders, W., and Liempt, J.A.M.v., Rec. Trav. Chim., 50, 999 (1931)
R15. Remy, H., and Koehn, M., Z. anorg. allgem. chem., 137, 365-88 (1924)
R16. Remy, H., and Seemann, W., Rec. trav. chim., 59, 516-25 (1940)
R17. Rengade, E., Ann. Chim. Phys., (8), 11, 348-432 (1907)
R18. Rengade, E., Compt. rend., 148, 1199-1202 (1909)
R19. Retgers, J.W., Z. phys. chem., 3, 497-61 (1889)
R20. Retartillo, N.M., and Moles, E., Anales soc. espan. fis quim., 31, 830-9 (1933)
R21. Ricci, J.E. and Doppelt, L., J.A.C.S., 66, 1985 (1944)
R22. Richards, T.W., and Wells, R.C., Z. phys. chem., 43, 465-74 (1903)
R23. Richmond, W.E., and Wolfe, C.W., Am. Mineral., 23, 799-804 (1938)
R24. Ridgway, R.E., Klein, A.A., and O'Leary, W.J., Trans. Electrochem. Soc., 70, 71-88 (1936)
R25. Rieck, G.D., Rec. trav. chim. 62, 427-30 (1943)(in German)
R26. Riesenfeld, E.H., and Chang, T.L., Z. Phys. Chem., 33B, 127-32 (1936)
R27. Rinne, F., Neues Jahrb. Min. Beilagebd., A58, 70 (1928)
R28. Rinne, F. and Kolb, R., Neues Jahrb. Min., 1910, II, 138-58
R29. Rinse, J., Rec. trav. chim., P.-B., 47, 28 (1928)
R30. Rivoir, L. and Abbad, M., Anales fis quim (Spain) 39, 306 (1943). C.A., 38, 1158 (1944)
R31. Robert, C., Helv. Phys. Acta., 9, 405-36 (1936)
R32. Roberts, E.J., and Fenwick, F., J.A.C.S., 50, 2125-47 (1928)
R33. Roberts, H.S., Phys. Rev., 23, 386-95 (1924)
R34. Roberts, H.S., and Merwin, H.E., Am. J. Sci., (5), 21, 149 (1931)
R35. Robertson, D.W., Ind. Eng. Chem., 28, 216-9 (1936)
R36. Robinson, P.L., and Scott, W.E., J. Chem. Soc., (London), 135, 972-9 (1932)
R37. Robinson, P.L., and Smith, H.C., J. Chem. Soc., (London), 129, 1263-82 (1926)
R38. Robson, H.L., J.A.C.S., 49, 2772-83 (1927)
R39. Rochow, E.G., An Introduction to the Chemistry of the Silicones, pp. 16,17,39-44,58,59,64,65 (John Wiley & Sons, New York and Chapman & Hall, London, 1946)
R40. Roeser, W.F., and Wensel, H.T., Bur. Stand. J. Res., 26, 273-87 (1941)
R41. Rollet, A.P., Compt. rend., 200, 1763-5 (1935)
R42. Rollet, A.P., Compt. rend., 202, 1863-5 (1936)
R43. Rollet, A.P., and Peng, C.M., Bull. Soc. Chim., (5), 2, 982-5 (1935)
R44. Rollier, M.A., Hendricks, S.R., and Maxwell, L.R., J. Chem. Phys., 4, 648-52 (1936)
R45. Rosicky, V., Z. Kryst. 45, 476 (1908)
R46. Ross, W.H., and Jones, R.M., J.A.C.S., 47, 2165-70 (1925)
R47. Rossini, F.D., and Jessup, R.S., Natl. Bur. Stand. J. Res., 21, 491-513 (1938)

R48. Rostkowski, A.P., J. Russ. Ges. (Chem.), 62, 2067 (1930)

R49. Rostkovskii, A.P., J. Gen. Chem,, (U.S.S.R.), 4, 1010-20 (1934)

R50. Roth, W.A., Z. angew. Chem., 42, 981 (1929)

R51. Roth, W.A., and Bertram, W., Z. Elektrochem., 35, 297-308 (1929)

R52. Roth, W.A., and Chall, P., Z. Elektrochem., 34, 185-99 (1928)

R53. Roth, W.A., and Schwartz, O., Ber., 61, 1539-45 (1928)

R54. Roth, W.A., and Troitzsch, H., Arch. Eisenhuettenw., 6, 79-83 (1932/1933)

R55. Roth, W.L., DeWitt, T.W., and Smith, A.J., J.A.C.S. 69, 2881-5 (1947)

R55a Roy, R. and Osborn, E.F., J.A.C.S. 71, 2086 (1949)

R56 Rothermel, J.J., Sun, K.-H. and Silverman, A., J. Am. Ceram. Soc., B2, 153 (1949)

R57. Roy, D.M., Roy, R. and Osborn, Bull. Am. Ceram. Soc., 28, 134 (1949)

R58. Roy, R., Roy, D.M. and Osborn, Bull. Am. Ceram. Soc., 28, 135 (1949)

R59. Ruby, W.R. and Looeland, R.P., J. Phys. Chem. 50, 345 (1946)

R60. Ruedorff, W. and Ruedorff, G., Z. anorg. chem., 253, 281 (1947)

R61. Rueger, Keram. Rundschau, 31, 99 (1923)

R62. Ruer, R., Z. anorg. allgem. chem., 49, 365-83 (1906)

R63. Ruer, R., and Kuschmann, J., Z. anorg. allgem. chem., 154, 69-78 (1926)

R64. Ruer, R., and Kuschmann, J., Z. anorg. allgem. chem., 166, 257-74 (1927)

R65. Ruff, O., Z. anorg. allgem. chem., 82, 373-400 (1913)

R66. Ruff, O., Z. anorg. allgem. chem., 206, 59-64 (1932)

R67. Ruff, O., Trans. Electrochem. Soc., 68, 87-109 (1935)

R68. Ruff, O., Ber., 69A, 181-194 (1936)

R69. Ruff, O., and Ascher, E., Z. anorg. allgem. chem., 183, 193-213 (1929)

R70. Ruff, O., and Ascher, E., Z. anorg. allgem. chem., 196, 413-20 (1931)

R71. Ruff, O., and Boucher, L.L., Z. anorg. allgem. chem., 219, 376-81 (1934)

R72. Ruff, O., Ebert, F., and Stephan, E., Z. anorg. allgem. chem., 180, 215-24 (1929)

R73. Ruff, O. and Fischer, J., Z. anorg. allgem. chem., 179, 161-85 (1929)

R74. Ruff, O. and Giese, M., Z. anorg. allgem. chem., 219, 143-8 (1934)

R75. Ruff, O. and Heinzelmann, A., Z. anorg. allgem. chem., 72, 63-84 (1911)

R76. Ruff, O. and Jellinek, E., Z. anorg. allgem. chem., 97, 312-36 (1916)

R77. Ruff, O. and Konschak, M., Z. Elektrochem., 32, 518 (1926)

R78. Ruff, O. and Kwasnik, W., Z. anorg. allgem. chem., 219, 65-81 (1934)

R79. Ruff, O. and Menzel, W., Z. anorg. allgem. chem., 219, 93-4 (1934)

R80. Ruff, O. and Schmidt, P., Z. anorg. allgem. chem., 117, 172-190 (1921)

R81. Ruff, O., and Vidic, E., Z. anorg. allgem. chem., 143, 163-82 (1925)

R82. Ruiss, I.G., and Uritzkaya, R.G., Compt. rend. acad. sci., U.S.S.R., 4, 213-6 (1934)

R82a Rundle, R.E., J.A.C.S., 69, 1719 (1947)

R83. Rundle, R.E., Baenziger, N.C., Wilson, A.S. and McDonald, R.A., J.A.C.S. 70, 99-105 (1948)

R84. Russell, H. Jr., Rundle, R.E., and Yost, D.M., J.A.C.S., 63, 2825-8 (1941)

R85. Ryss, I.G. and Polyakova, E.M., Zhur. Obsheher Kkim. (J. Gen. Chem.) 18, 286-8 (1948) (in Russian)

S 1. Safford, H.W., Private communication, 1941

S 2. Safford, H.W.and Silverman, A., J. Am. Ceram. Soc. 30, 203-11 (1947)

S 3. Sagawa, T., Sci. Rept. Tohoku Imp. Univ., 1st. Ser., 22, 959-71 (1933)

S 4. Samson, S. and Sillen, L.G., Arkiv Kemi, Mineral. Geol. 25A, No. 21, 16 pp. (1947)

S 5. Samuel, R. and Lorenz, L., Z. Phys. 59, 65 (1930)

S 6. Schairer, J.F., and Bowen, N.L., Am. J. Sci., (5), 35A, 289-309 (1929)

S 7. Schaller, W.T., Am. Mineral., 12, 24-5 (1927)

S 8. Schaller, W.T., U.S. Geol. Surv. Shorter contrib. to general Geol., 1929

S 9. Schaller, W.T., U.S. Geol. Surv. Prof. Pap., No. 158, 137-70 (1930)

S10. Schaller, W.T., Am. Mineral., 23, 575-82 (1938)

S11. Scharf, P.T., Private communication to K.H. Sun

S12. Schenk, P.W., and Rehaag, H., Z. anorg. allgem. chem., 233, 403-10 (1937)

S13. Schischkin, N., Z. anorg. allgem. chem., 189, 289-96 (1930)

S14. Schmidt, J.M., Bull. soc. chim. (4), 39, 1686 (1926)

S15. Schoene, E., Ber., 6, 1172-5 (1873)

S16. Schoep, A., Am. Mineral. 32, 344-50 (1947)

S17. Schroeder, A., Z. Kryst., 66, 493-4 (1928)

S18. Schroeder, A., Z. Kryst., 67, 485-542 (1928)

S19. Schubert, K. and Seitz, A., Z. Naturforsch. 1, 321 (1946)

S20. Schuetz, W., Z. physik. chem., 31B, 292-308 (1935)

S21. Schulman, J.H. and Schumb, W.C., J.A.C.S. 65, 878-83 (1943)

S22. Schulten, A.de, Compt. rend., 100, 877 (1885)

S23. Schulten, A.de, Bull. Soc. Chim. (3), 1, 475 (1889)

S24. Schulten, A.de, Bull. Soc. Chim., (3), 29, 720-4 (1903)

S25. Schulten, A.de, Bull. Soc. Min., 27, 100 (1904)

S26. Schulze, G.E.R., Z. Phys. Chem., 24B, 215-40 (1934)

S27. Schulze, G.E.R., Z. Kryst., 89, 477-80 (1934)

S28. Schulze, G.E.R., J.A.C.S., 57, 883 (1935)

S29. Schulze, G.E.R., Z. Phys. Chem., 32B, 430-2 (1936)

S30. Schumann, Centr. Min. Geol., (A), 1933, 122

S31. Schumar, J.F., AECD 1851 (1948), Uranium, Thorium and Beryllium Melting and Fabrication, Uranium $\gamma \rightarrow \beta$ 665° C, $\beta \rightarrow \alpha$ 775° C, M.P. 1125° C

S32. Schumb, W.C., and Gamble, E.L., J.A.C.S., 52, 4302-8 (1930)

S33. Schumb, W.C., and Gamble, E.L., J.A.C.S., 53, 3191-2 (1931); 54, 583-90 (1932)

S34. Schumb, W.C. and Rittner, E.S., J.A.C.S., 65, 1055-60 (1943)

S35. Schwarz, R., Z. anorg. allgem. chem., 176, 236-40 (1928)

S36. Schwarz, R., Ber. 62, 2477-83 (1929)

S37. Schwarz, R., and Haacke, A., Z. anorg. allgem. chem., 115, 87-99 (1921)

S38. Schwarz, R., and Heinrich, F., Z. anorg. allgem. chem., 205, 43-8 (1932)

S39. Schwarz, R., and Heinrich, F., Z. anorg. allgem. chem., 209, 273-6 (1932)

S40. Schwarz, R., and Lewinsohn, M., Ber., 63, 783-7 (1930)

S41. Schwarz, R. and Pflugmacher, A., Ber. 75B, 1062-71 (1942); cf. C.A. 34, 1267^8

S42. Schwarz, R., Schenk, P.W., and Giese, H., Ber., 64, 362-8 (1931)

S43. Schwarz, R., and Trageser, G., Z. anorg. allgem. chem., 225, 142-50 (1935)

S44. Schwiersch, H., Chem. Erde, 8, 252-315 (1933)

S45. Seaborg, G.T. and Perlman, I., Rev. Mod. Phys., 20, 585 (1948)

S46. Selmcourt, M.de, Proc. Phys. Soc., (London), 52, 348-52 (1940)

S47. Senff, H., and Klemm, W., Z. anorg. allgem. chem., 242, 92-6 (1939)

S48. Seward, R.P., J.A.C.S., 55, 2741 (1933)

S49. Seward, R.P., J.A.C.S., 67, 1189 (1945)

S50. Shannon, E.V., Proc. U.S. Nat. Museum, 60, Art. 22, 1922

S51. Shemtschushny, S., and Rambach, F., Z. anorg. allgem. chem. 65, 403-28 (1910)

S52. Shepherd, E.S., Rankin, G.A., and Wright, F.E., Am. J. Sci., (4), 28, 293-333 (1909)

S53. Shugam, E.A. and Zhdanov, G.S., Acta Physico Chim., U.R.S.S., 20, 247 (1945)

S54. Sidgwick, N.V., and Gentle, J.A.H.R., J. Chem. Soc., (London), 121, 1837-43 (1922)

S55. Sidgwick, N.V., and Lewis, N.B., J. Chem. Soc., 129, 1287 (1926)

S56. Sierra, An. Soc. Espan. fis. quim., 27, 220 (1929)

S57. Sieverts, A., and Schreiner, L., Z. anorg. allgem. chem., 219, 105-12 (1934)

S58. Sillen, L.G. and Lundborg, K., Z. anorg. chem. 252, 2-9 (1943)

S59. Sillen, L.G. and Sundvall, H., Arkiv Kemi, Min. Geol. 17A, No. 10, 1 (1943)

S60. Simon, A., Z. anorg. allgem. chem., 165, 31-40 (1927)

S61. Simon, A., Z. anorg. allgem. chem., 185, 300-4 (1929)

S62. Simons, J.H., J.A.C.S., 52, 3488-93 (1930)

S63. Simons, J.H., and Jessop, G., J.A.C.S., 53, 1263-6 (1931)

S64. Simons, J.H. and Powell, M.G., J.A.C.S., 67, 75 (1945)

S65. Slawson, C.B., Am. Mineral., 14, 160-1 (1929)

S66. Smith, H.W. Jr., and Colby, M.Y., Z. Kryst., 103, 90-5 (1940)

S67. Smith, W.C., Bannister, F.A. and Hey, M.H., Nature 154, 336-7 (1944)

S68. Smith, W.T. Jr. and Long, S.H., J.A.C.S. 70, 354-6 (1948)

S69. Smithsonian Physical Tables, 8 Revised Ed. by F.E. Fowle, Smithsonian Institution, Washington, D.C. 1932.

S70. Smits, A., and Beljaars, E., Z. Phys. Chem., 167A, 273-94 (1933)

S71. Smits, A., and Lange, W. de, J. Chem. Soc., 131, 2944-52 (1928)

S72. Smyth, C.P., and Hitchcock, C.S., J.A.C.S., 55, 1830-40 (1933)

S73. Smyth, H.D., Atomic Energy for Military Purposes p. 40 (Princeton University Press, 1945)

S74. Snow, R.B., J. Am. Ceram. Soc. 26, 11 (1943)

S75. Sørum, H., Kgl. Norske Videnskab. Selshabs. Forh. 15, 39 (1934)

S76. Sosman, R.B., The Properties of Silica, A.C.S. Monograph Series No. 37, Chemical Catalog Co., New York, N.Y. 1927

S77. Sosman, R.B., J. Am. Ceram. Soc., 16, 54-7 (1933)

S78. Sosman, R.B., J. Am. Ceram. Soc., 16, 60-8 (1933)

S79. Sosman, R.B., Private Communications, April 4, 1941

S80. Sosman, R.B., and Anderson, O., Composition-Temperature Phase Equilibrium Diagrams. Research Lab., U.S., Steel Corp., Kearny, N.S. 1934.

S81. Sosman, R.B., and Hostetter, J.C., J.A.C.S., 38, 807-33 (1916)

S82. Southard, J.C., and Nelson, R.A., J.A.C.S., 59, 911-6 (1937)

S83. Southard, J.C., and Royster, P.H., J. Phys. Chem., 40, 435-8 (1936)

S84. Sowa, F.J., Kroeger, J.W., and Nieuwland, J.A., J.A.C.S., 57, 454-6 (1935)

S85. Spandan, H. and Kohlmeyer, E.J., Z. anorg. chem., 254, 65 (1947)

S86. Spangenberg, K., Z. Krist. 57, 494-534 (1922)

S87. Spangenberg, K., Naturwiss., 15, 266 (1927)

S88. Spitsym, V.I., J. Gen. Chem,, (U.S.S.R.), 17, 11 (1947)

S89. Srebrov, B., Kolloid Z., 71, 293-7 (1935)

S90. Stackelberg, M.v., and Schnorrenberg, E., Z. Phys. Chem., 27B, 37-49 (1934)

S91. Staesche, M. and Wetzel, J., Metall n Erg. 41, 101 (1944)

S92. Stahl, S., Arkiv Kemi, Min. Geol. 17B, No. 5, 1 (1943)

S93. Staples, L.W., Am. Mineral., 20, 112-19 (1935)

S94. Starabba, Boll, Soc. Geol. Ital., 48, 259 (1930)

S95. Stein, G., Z. anorg. allgem. chem., 55, 159-74 (1907)

S96. Sterba-Boehm, S.S., and Melichar, M., Chem. Abs., 29, 3617 (1935)

S97. Stock, A., Praetorius, P., and Priess, O., Ber., 58, 1571-80 (1925)

S98. Stoehr, H., Z. anorg. allgem. chem., 242, 138-44 (1939)

S99. Stokland, I.K.. Kgl. Norske Videnskab. Selskabs Forh. 19, No.10, 33-6 (1946)(Pub. 1947)(in English)

S100. Stoklasa, J., Z. anorg. allgem. chem., 3, 74 (1893)

S101. Stout, J.W. and Jones, W.M., Phys. Rev., 71, 582 (1947)

S102. Strada, M., and Schwendimann, G., Gazz. Chim. Ital., 64, 662-74 (1934)

S103. Straumanis, M., and Strenk, C., Z. anorg. allgem. chem., 213, 301-9 (1933)

S104. Stryk, B. and MacGillavry, C.H., Rec. trav. chim. 62, 705-12 (1943)(in English)
S105. Stringham, B.F., Am. Mineral. 31, 395-400 (1946)
S106. Strong, J., and Brice, R.T., J. Opt. Soc., Am., 25, 207-10 (1935)
S107. Strotzer, E.F., Schneider, O., and Biltz, W., Z. anorg. allgem. Chem., 243, 307-21 (1940)
S108. Strotzer, E.F. and Zumbusch, M., Z. anorg. allgem. chem. 247, 415-28 (1941); cf. c.a. 36, 1253^{6}
S109. Stroupe, J.D., J.A.C.S. 71, 569 (1949)
S110. Strunz, H., Z. Krist. 95, 1-8 (1936)
S111. Strunz, H., Naturwissenschaften 30, 531 (1942); Chem. Zentr. 1943, I, 1139-40
S112. Stuckert, L., Sprechsaal, 68, 321-4, 337-9, 353-5, 369-73 (1935)
S113. Süe, P., Compt. rend., 198, 1696-8 (1934)
S114. Sugden, S., J. Chem. Soc., (London), 130, 1173-86 (1927)
S115. Sun, K.H., Calculation of density from X-Ray Data, (unpublished)
S116. Sun, K.H., Unpublished data.
S117. Sun, K.H. and Scharf, P.T., Unpublished data.
S118. Sun, K.H., and Silverman, A., J. Am. Ceram. Soc., 24, 160-7 (1941)
S119. Sun, L.L. and Sun, K.H., Calculation of Density from X-Ray Data (Unpublished)
S120. Swayze, M.A., Am. J. Sci., 244, 1-30, 65-94 (1946)
S121. Switzer, G., Am. Mineral., 23, 409-11 (1938)

T 1. Tabet, M., Gazz. Chim. Ital., 63, 679-80 (1933)
T 2. Tables annuelles de constantes et donnees numeriques de chemie de physique, de biologie et de technologie, 10 volumes plus 3 volumes index, edited by C. Marie, McGraw-Hill Book Co., New York, 1912-1932
T 3. Tamaru, S., and Shiomi, K., Z. phys. chem., 171A, 221-33(1935)
T 4. Tammann, G. (Translated by Mehl, R.F.) States of Aggregation, D. Van. Nostrand Co., N.Y., 1925.
T 5. Tammann, G., and Jenckel, E., Z. anorg. allgem. chem., 184, 416-20 (1929)
T 6. Tanaka, Y., J. Chem. Soc., (Japan), 62, 199-203 (1941)
T 7. Tarbutton, G., Egan, Jr., E.P., and Frary, S.G., J.A.C.S., 63, 1782-9 (1941)
T 8. Tarr, O.F., Darrin, M. and Tubbs, L.G., J.A.C.S., 66, 929-30 (1944)
T 9. Tavasci, B., Tonind. Ztg., 61, 717-9, 729-31 (1937)
T 10. Taylor, A.C. and Walden, B.V.deG., J.A.C.S., 66, 842-3 (1944)
T 11. Taylor, H.S., J.A.C.S., 56, 2643 (1934)
T 12. Taylor, H.S., and Jungers, J.C., J.A.C.S., 55, 5057-8 (1933)
T 13. Taylor, H.S., and Selwood, P.W., J.A.C.S., 56, 998-9 (1934)
T 14. Taylor, N.W., Z. Phys. Chem., B9, 241-64 (1930)
T 15. Taylor, T.I., and Klug, H.P., J. Chem. Phys., 4, 601-7 (1936)
T 16. Taylor, W.C., Bur. Stand. J. Res., 21, 315-25 (1938)

T17. Taylor, W.C., Bur. Stand. J. Res., 27, 311-23 (1941)

T18. Taylor, W.C., J. Research Natl. Bur. Standards, 29, 439 (1942); (R.P. 1512)

T19. Terem, H.N., Compt. rend., 222, 1387 (1946)

T20. Terpstra, P., Z. Krist., 97, 229-33 (1937)

T21. Terres, E., and Behrens, H., Z. phys. chem., A139, 695-716 (1928)

T22. Thibault, N.W., Am. Mineral., 29, 249-327 (1944)

T23. Thiel, A., and Luckmann, H., Z. anorg. allgem. chem., 172, 353-71 (1928)

T24. Thilo, E., Ber., 70, 2373-81 (1937)

T25. Thomas, J.S., and Rule, A., J. Chem. Soc., (London), 99, 871-6 (1911)

T26. Thomas, J.S., and Rule, A., J. Chem. Soc., (London), 111, 1063-85 (1917)

T27. Thomas, V., Compt. rend., 135, 1051-4 (1902)

T27a Thompson, R.M., Univ. Toronto Studies, Geol. Ser. No. 51, 35-40 (1946)(Pub. 1947)

T28. Thorpe, T.E. and Watts, J.I., J. Chem. Soc., (London), 37, 102-17 (1880)

T29. Thorvaldson, T., and Grace, N.S., Canad. J. Res., 1, 36-47 (1929)

T30. Thorvaldson, T., Grace, N.S., and Vigfusson, V.A., Canad. J. Res., 1, 201-13 (1929)

T31. Thorvaldson, T., and Schneider, W.G., Can. J. Res., 19B, 109-15 (1941)

T32. Tiede, E., and Schleede, A., Ber., 53, 1717-21 (1920)

T33. Tiede, E., and Schleede, A., Centr. Miner. Geol., 1921, 154

T34. Tiede, E., and Thimann, M., Ber., 59, 1703-6 (1926)

T35. Tilden, W.A., J. Chem. Soc., 45, 266-70 (1884)

T36. Tilley, C.W., Tscherm. Mitt., 43, 406 (1933)

T37. Tilley, C.W., Z. Krist. B. Mineral. petrograph. Mitt., 43, 406 (1933)

T38. Tilton, L.W., and Taylor, J.K., Bur. Stand. J. Res., 13, 207-9 (1934)

T39. Tokody, L., Z. anorg. allgem. chem., 169, 51-6 (1928)

T40. Toropov, N.A., Compt. rend. acad. sci., U.R.S.S. 1, No. 2-3, 147-9 (1935)

T41. Toropov, N.A., Compt. rend. acad. sci., U.R.S.S., 23, 74-5 (1939)

T42. Toropow, N.A., and Konovalow, P.F., Compt. rend. Acad. Sci., U.R.S.S., 20 (9), 663-4 (1938)

T43. Toropov, N.A., and Konovalov, P.F., J. Phys. Chem. (U.S.S.R.), 14, 1103-10 (1940)

T44. Toropov, N.A., and Konovalov, P.F., Compt. rend. acad. sci. U.R.S.S. 40, 155-7 (1943)(in English)

T45. Toropov, N.A., and Stukalova, M.M., Compt. rend. acad. sci., U.R.S.S. 27, 974-7 (1940)

T46. Tosterud, M., J.A.C.S., 48, 1-5 (1926)

T47. Travers, A., and Zahabi, H., Compt. rend., 206, 55-7 (1938)

T48. Troemel, G., Veroff. Kais.-Wilh.-Inst. Silicatforsch., 3, 103-31 (1930)

T49. Troemel, G., Z. Phys. Chem., 158, 422-32 (1932)
T50. Troemel, G., Mitt. Kais. Wilh. Inst. Eisenforsch., 14, 25-36 (1932)
T51. Trombe, F. and Foex, M., Compt. rend., 217, 501 (1943)
T52. Trombe, F. and Foex, M., Am, Chim. 19, 417 (1944)
T53. Trousil, Z., Chem. Abs., 32, 7363 (1938)
T54. Tubandt, C., and Haedicke, M., Z. anorg. allgem. chem., 160, 297-317 (1926)
T55. Tunell, G., and Ksand, C.J., J. Washington Acad. Sci., 26, 507-9 (1936)
T56. Tutton, A.E.H., J. Chem. Soc., (London), 87, 1183-9 (1905)
T57. Tutton, A.E.H., Proc. Roy. Soc., (London), 79,A, 351-82 (1907)
T58. Tyndall, E.P.T., Phys. Rev., (2), 21, 162-80 (1923)
T59. Tzentnershver, M., and Blumenthal, M., Bull. intern. acad. polonaise, Classe sci. math. nat., 1935A, 540-50

U 1. Urbain, G., and Lacombe, H., Compt. rend., 138, 627-9 (1904)
U 2. U.S. Bureau of Standards, Miscellaneous Publication M 126, Feb. 26, 1937
U 3. Ussanowitsch, M., Z. phys. chem., 119, 139-40 (1926)

V 1. Van Dusen, M.S. and Dahl, A.I., Science 106, 428 (1947)
V 2. Vasenin, F.I., Tsement, 5, 36-8 (1938)
V 3. Vasenin, F.I., Chem. Zentr., 1940, I, 2296-7
V 4. Vasenin, F.I., J. Gen. Chem., (U.S.S.R.), 17, 450 (1947)
V 5. Vasenin, F.I., Doklady Acad. Nauk. S.S.S.R., 59, 1321 (1948)
V 6. Vasenin, F.I., Zhur. Priklad. Khim. (J. Applied Chem.) 21, 429 (1948)
V 7. Venable, F.P., and Bell, J.M., J.A.C.S., 39, 1598-1608 (1917)
V 8. Viana, J.G., and Moles, E., Anal. soc. espan. fis. quim., 27, 159 (1929)
V 9. Viard, G., Compt. rend., 109, 142 (1889)
V10. Vigfusson, V.A., Bates, G.N., and Thorvaldson, T., Canad. J. Res., 11, 520-9 (1934)
V11. Villiers, J.E. de and Walt, C.F.J. van der, Am. Mineral. 30, 629 (1945)
V12. Vogel, R. and Hartung, A., Arch. Eisenhuttenn. 15, 413 (1942)
V13. Voigt, A., and Biltz, W., Z. anorg. allgem. chem., 133, 277-305 (1924)
V14. Volkov, N.N., and Bergman, A.G., Compt. rend. acad. sci., U.R.S.S., 27, 967-9 (1940)
V15. Vorlaender, D., and Dalichau, G., Ber., 66, 1534-6 (1933)
V16. Vorlaender, D., Hollatz, J., and Fischer, J., Ber., 65, 535-8 (1932)
V17. Vorlaender, D., and Kaascht, E., Ber., 56, 1157-62 (1923)

W 1. Wagner, G., and Lippert, L., Z. Phys. Chem., B31, 263-74(1936)
W 2. Wagner, G., and Lippert, L., Z. Phys. Chem., 33B, 297-303(1936)
W 3. Waldeck, W.F., Lynn, G., and Hill, A.E., J.A.C.S., 54, 928-36 (1932)
W 4. Waldeck, W.F., Lynn, G., and Hill, A.E., J.A.C.S., 56, 43-7 (1934)

W 5. Wallmark, S. and Westgren, A., Arkiv. Kemi. Mineral. Geol., 12B No. 35, 4 pp. (1937)

W 6. Walmsley, H.P., Phil. Mag., (7), 7, 1097-1112 (1929)

W 7. Warf, J.C., A.E.C.D.-2413. Nuclear Abstract II, 355 (1949)

W 8. Warren, C.H., Am. J. Sci., (5), 2, 120-8 (1921)

W 9. Warren, H.V., Univ. Toronto Studies, Geol. Ser. No. ?, 50, 75 (1940)

W10. Wartenberg, H.v., Z. anorg. allgem. chem., 241, 381-94 (1939)

W11. Wartenberg, H.v., Z. anorg. allgem. chem., 242, 406-12 (1939)

W12. Wartenberg, H.v., Z. anorg. allgem. chem., 244, 337-47 (1940)

W13. Wartenberg, H.v., Naturwissenschaften 29, 771 (1941)

W14. Wartenberg, H.v., Z. anorg. allgem. chem. 249, 100-12 (1942); cf. C.A., 36, 6097^{e}

W15. Wartenberg, H.v., and Eckhardt, K., Z. anorg. allgem. chem., 232, 179-87 (1937)

W16. Wartenberg, H.v., and Gurr, W., Z. anorg. allgem. chem., 196, 374-83 (1931)

W17. Wartenberg, H.v., and Prophet, E., Z. anorg. allgem. chem., 208, 369-79 (1932)

W18. Wartenberg, H.v., and Reusch, H.J., Z. anorg. allgem. chem. 207, 1-20 (1932)

W19. Wartenberg, H.v., Reusch, H.J., and Saran, E., Z. anorg. allgem. chem., 230, 257-76 (1937)

W20. Wartenberg, H.v., and Schulz, H., Z. Elektrochem., 27, 568-73 (1921)

W21. Wartenberg, H.v., and Werth, H., Z. anorg. allgem. chem., 190, 178-84 (1930)

W22. Wartman, F.S., Am. Inst. Mining. Met. Engrs., Tech. Pub., No. 514, 12 pages (1933)

W23. Washburn, E.W., and Bunting, E.N., Bur. Stand. J. Res., 12, 239 (1934)

W24. Washington, H.S., and Merwin, H.E., Am. Mineral., 12, 233-52 (1927)

W25. Wedekind, E., and Horst, C., Ber., 48, 105-12 (1915)

W26. Wehrli, M. and Gutzwiller, N., Helv. Phys. Acta. 14, 307-9 (1941)

W27. Weibke, F., Laar, J. and Meisel, K., Z. anorg. allgem. chem., 224, 49-61 (1935)

W28. Weinstock, B. and Crist, R.H., J. Chem. Phys. 16, 436-41 (1948)

W29. Wejnarth, A., Metall u. Erz., 31, 73-7 (1934)

W30. Wells, C., Ackley, R.A., and Mehl, R.E., Trans. Am. Soc. Metals, 24, 46-66 (1936)

W31. Wells, H.L., and Beardsley, H.P., Am. Chem. J., 26, 275-8 (1901)

W32. Wells, L.S., Bur. Stand. J. Res., 1, 951-1009 (1928)

W32a Welo, L.A., and Baudisch, O., Phil. Mag., 24, 80-7 (1937)

W33. Wendekamm, K., Z. Kryst., 85, 169-98 (1933)

W34. Wensel, H.T., J. Am. Ceram. Soc., 19, 81-6 (1936)

W35. Wensel, H.T., Private Communications, April, 1941.

W36. Wentrup, H., Arch. Eisenhuetteniv., 9, 57-60 (1935)

W37. West, C.D., Z. Kryst., 88, 97 (1934)

W38. West, C.D., J. Phys. Chem., 39, 493-507 (1935)

W39. White, J., Howat, D.D., and Hay, R., J. Roy. Tech. Coll. (Glasgow) 3, 231-40 (1934)
W40. White, H.E., and Shremp, R.M., J. Am. Ceram. Soc., 22, 185-9 (1939)
W41. Willems, Physica, 7, 203 (1927)
W42. Winchell, A.N., The Microscopic Characters of Artificial Inorganic Solid Substances or Artificial Minerals, 2nd. Ed. John Wiley & Sons, N.Y. 1931
W42a Winchell, A.N., Elements of Optical Mineralogy, 3rd. Ed., Pt. 2, Description of Minerals, John Wiley & Sons, New York, N.Y. 1933
W43. Winchell, A.N., The Optical Properties of Organic Compounds. The University of Wisconsin Press, 1943.
W44. Winchell, A.N., Am. Mineral., 20, 562-8 (1935)
W45. Winchell, A.N., Am. Mineral., 26, 422-8 (1941)
W46. Windmaisser, F., Osterr. Chem.-Ztg. 45, 201-10 (1942); cf. C.A. 37, 2675^7
W47. Windsor, V. and Cady, G.H., J.A.C.S., 70, 1500-2 (1948)
W48. Winkler, H.G.F., Am. Mineral. 32, 131-6 (1947)
W49. Winter, H., Versuche zur Bildung von Apatiten und wagneritahnlichen Verbindungen des Mg. Ba und Sr.; Diss. Universitat zu Leipzig, 1913, pp 1-46 (Neues Jahrb. Min. I, 206 (1914)) Cited in Kelley, K.K., U.S. Bureau Mine Bulletin, No. 393, 1936.
W50. Wirtz, K., Naturwissenschaften 30, 330-2 (1942)
W51. Woehler, L., and Flick, K., Ber., 67B, 1679-83 (1934)
W52. Woehler, L., Plueddemann, W., and Woehler, P., Ber., 41, 703-17 (1908)
W53. Wolf, G., Compt. rend., 200, 1203-5 (1935)
W54. Woloskow, A., Izvestija Peterburgskago politechn. Inst., (russ.) 15, 433 (1911)
W55. Woloskow, A., N. Jahrb. Mineral. 1913, I, 35
W56. Wood, E.A., P.R. 72, 436 (1947)
W57. Wulff, P., and Cameron, H.K., Z. Phys. Chem., 10B, 347-67 (1930)
W58. Wulff, P., and Heigl, A., Z. Kryst. 77, 84-121 (1931)
W59. Wulff, P., and Heigl, A., Z. phys. chem., A 153, 187-209 (1931)
W60. Wulff, P., and King, A., Z. Krist., 87, 72-99 (1934)
W61. Wulff, P., and Schaller, D., Z. Krist., 87, 43-71 (1934)
W62. Wyart, J., and Chatelain, P., Bull. soc. franc. mineral., 61, 121-6 (1938)
W63. Wyckoff, R.W.G., The Structure of Crystals, A.C.S. Monograph Series No. 19, Chemical Catalog Co., New York, 1931
W63a Wyckoff, R.W.G., The Structure of Crystals, A.C.S. Monograph Series No. 19A, Chemical Catalog Co., New York, 1935.
W64. Wyckoff, R.W.G., Crystal Structures, Section I. Interscience Publishers, Inc., N.Y. 1948.
W65. Wyckoff, R.W.G., and Morey, G.W., Am. J. Sci., (5), 12, 419-40 (1926)
W66. Wyckoff, R.W.G., and Posnjak, E., J.A.C.S., 44, 30-6 (1922)
W67. Wyk, van H.J., Z. anorg. anorg. chem., 48, 1-52 (1906)

Y 1. Yakowitz, M.L., and Jorgensen, P.S., Ind. Eng. Chem., Analy. Ed., 9, 204 (1937)
Y 2. Yamada, T. and Nakanishi, Y., J. Soc. Chem. Ind. Japan 47, 491-3 (1944)
Y 3. Ygberg, E.R., Geol. Foren. Forh. 63, 394-404 (1941); Chem. Zentr. 1942, I, 2246
Y 4. Yong, W.F. de, and Willems, H.W.V., Physica, 7, 76 (1927)
Y 5. Yoshiki, B., Proc. Imp. Acad., (Tokyo), 10, 417-20 (1934)
Y 6. Yost, D.M., and Claussen, W.H., J.A.C.S., 55, 885-91 (1933)

Z 1. Zachariasen, W., Z. phys. chem., 119, 201-13 (1926)
Z 2. Zachariasen, W., Z. phys. chem., 123, 134-50 (1926)
Z 3. Zachariasen, W., Z. phys. chem., 124, 277-84 (1926)
Z 4. Zachariasen, W., Z. physik. chem., 124, 436-48 (1926)
Z 5. Zachariasen, W.H., Z. Kryst. 71, 514 (1926)
Z 6. Zachariasen, W., Z. phys. chem., 128, 417-20 (1927)
Z 7. Zachariasen, W., Sk. Norske Vid. Akad. Oslo., I. Math.-Naturv. Kl. 1928, No. 4, 1-165
Z 8. Zachariasen, W.H. J. Chem. Phys., 5, 919-22 (1937)
Z 9. Zachariasen, W.H., Z. Krist. 98A, 266-274 (1937)
Z10. Zachariasen, W.H., M.D.D.C.-1151 (1947)
Z11. Zachariasen, W.H., Acta Cryst. 1, 263-265 (1948)
Z12. Zachariasen, W.H., Acta Cryst. 1, 265-268 (1948)
Z13. Zachariasen, W.H., Acta Cryst. 1, 268-273 (1948)
Z14. Zachariasen, W.H., Acta Cryst. 1, 277-281 (1948)
Z15. Zachariasen, W.H., Acta Cryst. 1, 281-285 (1948)
Z16. Zachariasen, W.H., Acta Cryst. 1, 285-287 (1948)
Z17. Zachariasen, W.H., J.A.C.S. 70, 2147-51 (1948)
Z18. Zachariasen, W.H., M.D.D.C.-1674, A.E.C., Abs. Dec. Doc. 11, 113 (1948)
Z19. Zachariasen, W.H., J. Chem. Phys. 16, 254, 425 (1948); also M.D.D.C.-1675 A.E.C., Abs. Dec. Doc. 11, 113 (1948)
Z20. Zachariasen, W.H., A.E.C.D.-2089, Nuclear Sci. Abs. 1, (3), 173 (1948)
Z21. Zachariasen, W.H., Acta Cryst. 2, (1), 57-60 (1949)
Z22. Zachariasen, W.H., Acta Cryst. 2, (1), 60-62 (1949)
Z22a Zachariasen, W.H., Acta Cryst. 2, (2), 94 (1949)
Z23. Zagorchev, B., Z. physik. chem. A182, 31-41 (1938)
Z24. Zambonini, F., Z. Kryst., 41, 58 (1906)
Z25. Zambonini, F., Bull. Soc. Min. France, 38, 206 (1915)
Z26. Zambonini, F., Gazz. Chim. Ital., 50, II, 128-46 (1920)
Z27. Zambonini, F., Compt. rend., 172, 1419-22 (1921)
Z28. Zambonini, F., Atti. Linc., (5), 31, II, 67 (1922)
Z29. Zambonini, F., Z. Krist., 58, 226-92 (1923), Chem. Abs., 18, 947 (1924)
Z30. Zambonini, F., Compt. rend., 176, 1473-5 (1923)
Z31. Zambonini, F., Atti. Accad. Lincei., (6), 3, 644-9 (1926)
Z32. Zambonini, F., and Ferrari, A., Atti. accad. Lincei, (6), 7, 283-91 (1928)
Z33. Zambonini, F., Bull. Soc. Min. France, 1930, 443
Z34. Zedlitz, O., Centr. Min. Geol. 1935A, 68-78

Z35. Zhdanov, G.S. and Sevast'yanov, N.G., J. Phys. Chem., (U.S.S.R.) 17, 326-35 (1943); cf. C.A. 37, 1911^1.

Z36. Zhdanov, G.S. and Shugam, E.A., Acta Physico Chim. U.R.S.S. 20, 253 (1945)

Z37. Zhirnova, N., J. Gen. Chem., (U.S.S.R.), 4, 1464-70 (1934)

Z38. Zhirnowa, N., Z. anorg. allgem. chem., 218, 193-200 (1934)

Z39. Zhuravlev, V.F., Doklady Akad, Nauk. S.S.S.R. 59, 1145-9 (1948)

Z40. Ziegler, G.E., Phys. Rev., 38, 1040-7 (1931)

Z41. Zimens, K.E., Z. phys. chem., 37B, 231-59 (1937)

Z42. Zintl, E., Braeuning, W., Grube, H.L., Krings, W., and Morawietz, W., Z. anorg. allgem. chem., 245, 1-7 (1940)

Z43. Zintl, E., Harder, A., and Dauth, B., Elektrochem., 40, 588-93 (1934)

Z44. Zintl, E., and Morawietz, W., Z. anorg. allgem. chem., 245, 12-5 (1940)

Z45. Zintl, E., and Morawietz, W., Z. anorg. allgem. chem., 245, 26-31 (1940)

Z46. Zintl, E., Morawietz, W., and Gastinger, E., Z. anorg. allgem. chem., 245, 8-11 (1940)

Z47. Zmaczynski, A., Roczniki Chem., 16, 486-501 (1936)

Z48. Zsivny, V. and Narray-Szabo-I.v., Schweiz. mineralog. petrog. Mitt. 27, 183 (1947)

The National Research Council

Membership and Organization.—The National Research Council is a cooperative organization of scientific men of America, including also a representation of men of affairs interested in engineering and industry and in the basic sciences upon which the applications of science depend. Its membership is largely composed of accredited representatives of about ninety national scientific and technical societies. Its essential purpose is the promotion of scientific research and of the application and dissemination of scientific knowledge for the benefit of the national strength and well-being.

The Council was established at the request of the President of the United States, by the National Academy of Sciences, under its Congressional charter to coordinate the research facilities of the country for work on military problems involving scientific knowledge. In 1918, by Executive Order, it was reorganized as a permanent body for the general encouragement of scientific research.

ted

JUL 13 1950

BULLETIN
OF THE
NATIONAL RESEARCH COUNCIL
NUMBER 119 JANUARY 1950

THE COMPOSITION OF MILKS

PUBLISHED BY THE NATIONAL RESEARCH COUNCIL
NATIONAL ACADEMY OF SCIENCES
WASHINGTON 25, D. C.

Announcements Concerning Publications
of the
National Research Council

The Proceedings of the National Academy of Sciences

is partly supported by the National Research Council which is represented officially on its Editorial Board and Executive Committee. It is open for the publication of papers to members of the National Research Council on the same terms as to members of the National Academy of Sciences.

Subscription rate for the *Proceedings* is $5 per year. Business address: Home Secretary, National Academy of Sciences, 2101 Constitution Ave., Washington 25, D. C.

The Bulletin of the National Research Council

presents monographs especially prepared by Committees of the Council or directories for general use in science compiled by the Council.

The *Bulletin* is published at irregular intervals. A discount of 20% from the list price of the *Bulletins* will be given to all who subscribe for the Series as issued, direct from the Publication Office. Numbers of the *Bulletin* are sold separately at prices based upon the cost of manufacture.

The Reprint and Circular Series of the National Research Council

renders available for purchase, at prices dependent upon the cost of manufacture, papers published or printed by or for the National Research Council. A discount of 20% from the list price will be given to all who subscribe for the Series as issued, direct from the Publication Office.

Orders for the *Bulletin* or the *Reprints and Circulars* of the National Research Council, accompanied by remittance made payable to the National Academy of Sciences, should be addressed: Publication Office, National Research Council, 2101 Constitution Ave., Washington 25, D. C.

A list of publications of the National Research Council with prices will be furnished upon request.

BULLETIN
OF THE
NATIONAL RESEARCH COUNCIL
NUMBER 119 JANUARY, 1950

THE
COMPOSITION OF MILKS

A Compilation of the Comparative Composition and Properties of Human, Cow, and Goat Milk, Colostrum, and Transitional Milk

Prepared by
ICIE G. MACY, HARRIET KELLEY, AND RALPH SLOAN
For
The Food and Nutrition Board
With the consultation of
The Committee on Maternal and Child Feeding
Icie Macy Hoobler, Chairman
C. Anderson Aldrich, James L. Gamble, George M. Guest,
J. P. Pratt, Genevieve Stearns, Harold C. Stuart,
and Alfred H. Washburn

PUBLISHED BY THE NATIONAL RESEARCH COUNCIL
NATIONAL ACADEMY OF SCIENCES
WASHINGTON, D. C.

FOREWORD

The Committee on Maternal and Child Feeding, which is responsible for this Bulletin, was organized in 1946 as one of sixteen standing committees of the Food and Nutrition Board. This is the Committee's second publication. The first publication, "The Advisability of Breast Feeding," appeared in the Journal of the American Medical Association, December 6, 1947. It was with deep regret that the Board learned of the death on October 7, 1949 of Dr. C. Anderson Aldrich, the author of this report and a devoted member of the Committee.

The present Bulletin presents a compilation of data which should be useful to practicing physicians, specialists, and research workers. Further reports from this Committee are in preparation. These include a review of the literature on the relation of maternal nutrition to infant health and a review on adolescent nutrition.

The Board is most appreciative of the unremitting efforts of the Committee.

Frank G. Boudreau, M.D.
Chairman, Food and Nutrition Board

PREFACE

Recognition of the importance of milk as a food for infants, children and adults, of the difficulties involved in gaining access to all available information on milk composition, and of the inadequacy of our knowledge of milk components—all were responsible for the decision of the Committee on Maternal and Child Feeding to make an extensive, critical survey of reports on the constituency of human, cow, and goat milks.

The Committee anticipated that a comprehensive survey of the literature on milk would be useful to research workers and to those whose interests are more directly in the feeding of infants. Recent evidence has shown that in infant feeding, quantitative interrelationships among various components of milk may be even more significant than levels of intake of specific factors. The compilation provides a broad base for estimation of the proportions of nutriments in secretion from the human breast and for evaluation of formulas composed with cow and goat milks. In addition, the assemblage emphasizes the inadequacy of existing information and directs attention to further possibilities for profitable investigation.

ICIE MACY HOOBLER, PH.D., SC.D.
Chairman, Committee on Maternal & Child Feeding

CONTENTS

PAGE

FOREWORD iii

PREFACE iv

EXPLANATORY TEXT FOR TABLE 1 2

COW COLOSTRUM 5

EXPLANATORY TEXT FOR SUMMARY TABLES 4–5 6

REFERENCES 6

TABLES

1. Compilation of the properties and composition of human colostrum, transitional and mature milk, mature goat milk and mature cow milk 18
2. Some properties and components of cow colostrum at intervals following parturition 52
3. The vitamin content of cows colostrum and milk during early lactation 52
4. Composition of proteins in mature human, goat and cow milks 53
5. Representative summary values of the properties and composition of human colostrum, transitional and mature milk, mature goat milk and mature cow milk 56

THE COMPOSITION OF MILKS

With the increasing understanding of the importance of milk as a food for human beings of all ages, the need has grown for an adequate compilation of data representing the chemical structure of milk as completely as possible The literature pertaining to the chemical structure of milk is voluminous, but it is scattered in numerous publications of many languages. Data of widely divergent value are reported in dissimilar quantitative terms and time has nullified the merit of some results by relegating methods into obsolescence. An extensive compilation of the comparative composition of the natural food of infants along with cow and goat milk has been made, therefore, in order to provide a ready reference source for the use of the physician or research scientist. The tabulation includes data for a greater number of individual components than any summary published to this time and is believed to delineate adequately the chemical structure of these milks as reliably as is possible with existing knowledge.

Data have been compiled from sources selected from among more than 1500 reports of investigations of the composition of the mammary secretion of "average," "normal," or "healthy" subjects. The literature provided numerous excellent reviews and discussions pertaining to the composition, production, secretion, and utilization of milk; many valuable data on the composition of milk, and colostrum, from other species; reports of the influence of environmental conditions, dietary, and processing; and, results from experimental and clinical investigations. Some communications reported data for constituents not included in this compilation because the analytical methods are not firmly established or conflicting results have been obtained. In deciding which data to include in the compilation, consideration was given to characteristics of the experimental subjects, methods of collecting samples, analytical techniques, diet, and environmental factors. Insofar as practical, all data were obtained from original reports to reduce possible errors from translation and reprinting. In a few instances when translation or access to the original would have been very difficult, data were taken as quoted by another author, or from *Chemical Abstracts*. A few values were taken as combined by one author from several publications of another (See ref. 64). For all values, references are given to the authors who presented the data and to the source from which the values were obtained. In references to *Chemical Abstracts* the journals of original publication also are cited. The gaps in available information represented by blank spaces in the tables indicate profitable areas for further investigation.

The difficulties encountered in attempts to assemble and combine from the literature representative values defining the chemical structure of milk are attributable to discrepancies in age, or breed, parity, diet, and individual nutritional and genetic factors of subjects; in procedures of collection, handling, preservation, and analysis of samples; in the intervals considered as periods of secretion of colostrum, transitional milk, and mature milk; and in methods of calculation and presentation of the results.

The composition of milk changes with establishment and progression of lactation; the concentrations of some constituents increase and of others decrease as the mammary structures adjust to the demands of milk production. Colostrum, the initial secretion of mammary glands, is composed of milk products elaborated prior to and following parturition, including whatever cellular constituents and debris remain from the process of preparation and "flushing-out" of the mammary glands and ducts prior to actual emptying of the secreted milk. Evidence indicates that the colostral period varies with the individual and lasts from one to five days. The changes in composition of the secretion occur more slowly in women than in cows or goats. For women, values for the second five days postpartum provide adequate data for evaluation of the rapidity with which the proportions of chemical constituents characteristic of colostrum are altered to become those of mature milk, although some investigators believe the transitional period extends beyond the tenth day postpartum and that mature milk does not flow for four to six weeks after delivery (132a).

The milk secreted by different individuals varies in composition between wide limits. Both the quality and the quantity of the milk secreted are in some degree dependent upon hereditary factors and may be altered by: the amounts and kinds of food consumed; environmental conditions (fresh air, sunshine, work, rest); disease; size and anatomic structure of the mammary gland; and, the emotional make-up of the subject. For any individual there is a definite physiologic capacity of the mammary gland, shown by both the total quantity of milk produced and the length of time lactation persists under normal conditions. Within limits, the quantity of milk secreted is controlled by the demand.

Table 1 presents the compiled mean and range values for 274 constituents and properties of human colostrum during the first five days postpartum, transitional milk during the second five days postpartum, and of mature human, goat, and cow milks. The 10 physical properties and 9 conventional fat characteristics are followed by a listing of 255 chemical components arranged as a general outline under ash components, fats and fatty acids, lactose, proteins and amino acids, and vitamins. Miscellaneous compounds are interspersed appropriately insofar as practicable. It is difficult to designate the actual number of separate chemical components because, for example, particular amino acids are replicated in the several proteins, and mineral elements enter into a complexity of compounds such as indicated by the specified inorganic salts. By eliminating replication of amino acid and other compounds and by counting inorganic elements singly, it is estimated that more than 100 separate components are listed.

The data for human milk represent subjects of various races, living in several countries, under widely different dietary regimens, and in divergent environments. Age, season, and number of prior lactation periods are not considered. Few values for mature human milk were obtained with samples secreted less than thirty days postpartum. All original data on the composition of human colostrum and milk obtained by the Research Laboratory of the Children's Fund of Michigan, both published and unpublished, were summarized in a recent publication (132a). The samples for the analyses summarized were obtained from approximately 200 women judged by their physicians to be representative healthy individuals. The majority of the samples represented pooled collections of all milk in both breasts at each regular nursing time during 24 hours. The thoroughly checked data in that summary (132a) have been used in this compilation in lieu of over two dozen original reports. In evaluating the nutritional adequacy of infants' intakes, especially during the puerperium, consideration of the volume secreted is inseparable from knowledge of the composition of the secretion. A mother may secrete a negligible amount of colostrum the first day postpartum or more than 80 ml. (132a), and on the second day as little as 56 ml. or as much as 385 ml. The volume of secretion per twenty-four hours normally continues to increase during the first eight or nine days postpartum, at which time the range for individual women is 800 to 1,800 ml. per day.

For cow and goat milks the values represent the several breeds (pure and mixed) commonly raised as milk animals, and samples obtained under varying conditions of feeding in widely scattered geographic regions. Age, season, previous "freshenings," and interval in lactations were not considered. Frequently, from reports of experimental work involving abnormal conditions only the values for "normal control" subjects were included.

The analytical samples employed by the investigators were obtained under many conditions. Samples for determinations of "trace" minerals usually were taken into glass containers direct from the animal and other precautions were frequently dictated by the analytical methods to be used. Human milk was obtained with mechanical or hand pumps, or by manual expression. Many of the samples represented complete 24-hour collections, or at least the entire amount of milk in one or both breasts at a feeding period, but some samples were composites of secretion collected from two or more women. The milk from animals was collected under varying conditions of control—largely dependent upon the analyses to be made. The values included in the tabulation were reported for raw, whole, commercial, or market milk. Some data for skim milk were calculated on a basis of whole milk with the fat values for the same samples, but only for constituents which are not found in appreciable quantities in fat.

Analytical values were reported with varying degrees of completeness and clarity. Data presented only in chart form could not be included. In some reports difficulty was encountered in determining whether results given were original, were taken from or cumulated with previous reports by the same authors, or were taken from the literature. Insofar as possible, duplicate representation was eliminated. In others, data were presented clearly but absence of a value such as fat content, dry weight, or ash, of the samples used, prevented calculation of the quantities actually in the milk. Unless sufficient information was given to establish the relationship with certainty, such figures were not included. A few data were not included because of extreme deviation from results of a number of other investigators.

In some instances the numbers of subjects, samples, or determinations represented by the data were not given. Some reports gave both means and ranges, but others gave only means, or range values without means. Unless noted, data for human colostrum and transitional milk are values specifically designated as within the first five days and second five days postpartum, respectively. Comparative data for human colostrum and mature milk, or for mature human, cow, and goat milks were not available for many constituents. When given, the number of determinations represented by a value was tabulated but, for the composition of mature human, cow, and goat milk especially, some of the best sources of values, notably United States Department of Agriculture bulletins, do not always give the number of analyses upon which means are based. From those reports which gave individual results for subjects, mean values weighted according to number of determinations are presented. When "number of subjects" alone was given or values were given for individuals, one determination was assumed for each subject.

Frequently, the same author(s) reported more than one mean value for a constituent in a single paper, or different values for the same constituent in separate papers. When the numbers of determinations, means, and ranges were given, averages weighted for number of samples were derived and are presented with the maximum range. If several references with the same senior author are given under one number in the list and are cited separately, arabic letters have been used to differentiate them.

The results of some analyses were reported in quantities per 100 cubic centimeters or per 100 ml.; others per 100 gm. Since the volume-weight correction is only a small factor in relation to the many variables involved in a compilation such as this, it has been ignored. Likewise, it has not been possible to make any allowances for improvements in acceptable chemical methods; for variations between groups of subjects designated as "normal" or "healthy"; or for dissimilar techniques of collection. When accepted conversion factors could be used, published data were recalculated to concentrations per 100 ml. of milk, but values such as those determined in "blue" or "yellow" units were not included.

International or U.S.P. units of vitamin A were converted to micrograms with factor 4.3, and of carotene with the factor 1.67.

Authors' values for protein were used when given. Total nitrogen was converted to protein with the factor 6.25; total protein nitrogen, with the factor 6.37. When values for total nitrogen and non-protein nitrogen were given the latter was subtracted from the total and the remainder converted with the factor 6.37. Nitrogen values for casein, whey lactoglobulin, and lactalbumin were converted to protein with the factor 6.37. Creatine, creatinine, uric acid, and urea values were derived from data for their nitrogen contents with the factors 3.1, 2.7, 3.0, 2.1, respectively.

Data for amino acid content of human and cow's milk reported by Block (17) were converted on the bases of 1.4 and 4.0 gm. of protein per 100 ml. of milk, respectively, in accordance with a personal communication from Dr. Block and with his approval values for colostrum were converted to values per 100 ml. of milk on the basis of 1.94 gm. of protein obtained by Macy (132). The amino acid values of Stokes (195) were converted on the basis of 12.4 gm. of total solids per 100 ml. of milk reported by Maynard (137).

The available values for the elemental composition and the amino acid, nitrogen, and sulfur distributions in the individual protein components of milk are given on the basis of 100 gm. of protein. In three instances (91, 116, 153) data presented as "lactalbumin" were shown by the authors to represent all of the protein except that in casein and the values were included with other values for "whey." The structure of lactoglobulin has not been firmly established and, although recent reports indicate that the more accurate designation is beta-lactoglobulin, only a few data are available. To provide for easier comparison of the published values and to enable calculation of the amino acid constituents on the basis of whole milk, values for beta-lactoglobulin have not been separated from those given for lactoglobulin.

COW COLOSTRUM

Recent interest in the possibility of using cow colostrum as a special food for infants has prompted the inclusion in this survey of a section on the composition of the early mammary secretion of cows (Tables 2 and 3). This additional contribution was made possible by the interest and cooperation of Dr. T. S. Sutton, Chairman of the Department of Agricultural Biochemistry, Ohio State University, who assembled the material and provided the tables and following discussion of the composition of cow colostrum:

"Colostrum, the secretion of the mammary gland for a short period following parturition, markedly differs from milk in composition in several respects. It has been described as 'an extremely rich solution of globulin in a fluid which otherwise strongly resembles milk' (8). As early as 1875, Eugling (61) had shown that colostrum was extremely rich in nitrogenous constituents.

"The more recent work of Engle and Schlag (57) shows the typical variations in the chemical composition and physical measurements of colostrum. The data presented in table 2 were obtained from one cow only, however the same authors presented similar data for two other cows which varied from these in only a minor way. Numerous other workers have presented data which are in substantial agreement with those of Engle and Schlag.

"Most of the early investigators partitioned the nitrogenous constituents of colostrum into two main groups namely casein and albumin. The latter fraction has more recently been partitioned into albumin and globulin fractions (38) and the globulin further partitioned by precipitation from sodium sulfate solutions (96) and more recently by electrophoresis (188a). In first milking colostrum the nitrogen is distributed approximately as follows: casein 31 per cent, albumin 6 per cent, globulin 55 per cent, and non-protein nitrogen 8 per cent, while in normal milk the approximate distribution is: casein 71 per cent, albumin 8 per cent, globulin 18 per cent, and non-protein nitrogen 3 per cent.

"Colostrum has been found to be a rich source of tryptophan (202a) which probably accounts for the lack of an apparent niacin requirement by the newborn calf.

"A complete vitamin analysis of colostrum is yet to be made. The work to date shows that colostrum is an extremely rich source of certain of the vitamins, while in the instance of others the concentration is no higher, if as high, as in normal milk.

"Numerous investigators (42, 50, 79, 83, 120a, 181, 194, 202b) have shown that colostrum is much richer in vitamin A activity (vitamin A and carotene) than normal milk. Although the vitamin A activity varies greatly between individual cows, the colostrum of the first milking following parturition is on the average 10 to 15 times as potent in this factor as normal milk.

"Investigations of the concentration of riboflavin has shown that first milking colostrum contains from 3 to 3.5 times as much riboflavin as normal milk (120c, 151, 202b, 206).

"Data obtained by Pearson and Darnell (151) show colostrum to be higher in thiamine, lower in pantothenic acid and about the same as milk in niacin content. Data are also reported (202b) which indicate somewhat higher concentrations of biotin in colostrum than in milk.

"Table 3 constructed from data reported by several of the authors cited above, shows typical vitamin composition of cows' colostrum and milk during the early days of lactation."*

SUMMARY TABLES

For use of those interested in the composition of milk in relation to its value as a food, representative values per 100 ml. of whole milk are presented in table 5 with supplementary data calculated from them. Since human, goat, and cow milks differ in the structure as well as quantity of each of their protein components, the averages of values available from table 1 for components of milk proteins are given in table 4.

In preparing these summary tables the values given in table 1 for each constituent of milk have been summarized by averaging the mean values for each component of human colostrum and transitional milk and of mature human, goat, and cow milk. Ranges given in table 1 without mean values were excluded from all averages for which any mean values were available. Number of determinations was not considered, thereby avoiding exclusion of values for which the number was not reported, as well as eliminating the possibility of the averages being influenced unduly by means representing large numbers of samples from subjects of one region, or analyzed under similar circumstances.

The data in tables 4 and 5 are therefore not to be considered as statistical averages of the data in table 1 but are proposed to provide reasonable representative values thereof. They are presented for general use as approximate values. Some are subject to recalculation by different methods and many undoubtedly will be revised as additional information is accumulated. The research worker must, necessarily, use the values reproduced in table 1 and may need to consult the original source to acquire precise knowledge of the conditions under which they were obtained. The summary tables emphasize the need for additional data which may eliminate incongruities and fill in the vacancies which appear.

REFERENCES

1. Abderhalden, R.: *Chem. Abst. 42:* 3054. Vitamin E content of human milk and cow milk. Biochem. Z. *318:* 47–53, 1947.
2. Aceto, G.: *Chem. Abst. 40:* 7320. Indican in human milk. Boll. soc. ital. biol. spec. *21:* 210–211, 1946.
3. Acharya, B. N., and Devadatta, S. C.: Compounds of phosphorus in milk. Proc. Indian Acad. Science *10B:* 221–228, 1939.

---

* Subsequent to the incorporation of Dr. Sutton's statement and tables in the manuscript, two publications dealing with the amino acid content of cow colostrum have appeared: (1) Amino Acid Composition of Bovine Colostrum and Milk, Sarkar, B. C. R., et al., J. Dairy Science 32, 671–678, 1949, (2) The Essential Amino Acid (except tryptophan) Content of Colostrum and Milk of the Cow and Ewe, Kuiken, K. A. and Pearson, P. B., J. Nutrition 39, 167-176, 1949. On the basis of these reports, representative essential amino acid values as per cent of crude protein for 17 samples of bovine colostrum are as follows: arginine 4.7, histidine 2.6, isoleucine 5.3, leucine 9.1, lysine 7.7, methionine 1.8, threonine 6.7, tryptophane 2.0, valine 8.1.

4. Anantakrishnan, C. P., Bhalerao, V. R., and Paul, T. M.: The glyceride composition of milk fat. Arch. Biochem. *18:* 35–40, 1948.

5. Ansbacher, S., and Supplee, G. C.: Cholesterol content and antirachitic activation of milk constituents. J. Biol. Chem. *105:* 391–404, 1934.

6a. Archibald, J. G.: Manganese in cow's milk. Milk Plant Monthly *30:* 36, 1941.

6b. ——: *Chem. Abst. 41:* 5644. Cobalt in cow milk. J. Dairy Science *30:* 293–297, 1947.

7. Aschaffenburg, R., and Temple, P. L.: The freezing point of milk. I. The freezing point and solids-not-fat content of milk of individual cows throughout a period of lactation. J. Dairy Research *12:* 315–321, 1941.

8. Associates of Rogers, L. A. Fundamentals of dairy science, Second edition. Reinhold Publishing Co., New York, 1935.

9. Baldwin, A. R., and Longenecker, H. E. Component fatty acids of early and mature human milk fat. J. Biol. Chem. *154:* 255–265, 1944.

10. Beach, E. F., Bernstein, S. S., Hoffman, O. D., Teague, D. M., and Macy, I. G. Distribution of nitrogen and protein amino acids in human and in cow's milk. J. Biol. Chem. *139:* 57–63, 1941.

11. Bechtel, H. E., and Hoppet, C. A. A study of the seasonal variation of vitamin D in normal cow's milk. J. Nutrition *11:* 537–549, 1936.

12. Bell, Marian. Studies on the composition of human milk. J. Biol. Chem. *80:* 239–247, 1928.

13. Benjamin, H. R., Hess, A. F., and Gross, J. The forms of magnesium in serum and milk. J. Biol. Chem. *103:* 383–390, 1933.

14. Birckner, V. The zinc content of some food products. J. Biol. Chem. *38:* 191–203, 1919.

15. Black, A., and Voris, L. A statistical study of the relationships between the constituents of milk. J. Agric. Research *48:* 1025–1032, 1934.

16. Bleyer, B., and Seidl, R. *In:* Mellander, O. (139).

17. Block, R. J., and Bolling, D.: The amino acid composition of cow and human milk proteins. Arch. Biochem. *10:* 359–363, 1946.

18. Blumberg, H., and Rask, O. S.: Spectrographic analysis of milk ashes. J. Nutrition *6:* 285–288, 1933.

19. Bomskov, C., and Nissen, H.: *Chem. Abst: 28:* 4774. Organic phosphorus compounds in goat and mare milk. Z. Kinderheilk. *54:* 775–778, 1933.

20a. Bosworth, A. W.: Studies of infant feeding. XIII. The caseins of cow's milk and human milk in their relation to infant feeding. The action of rennin on casein. Am. J. Dis. Children *22:* 193–201, 1921.

b. ——: Studies of the fat of human milk. J. Biol. Chem. *106:* 235–244, 1934.

c. ——, and Giblin, L. A.: The casein of human milk. J. Biol. Chem. *35:* 115–117, 1918.

d. ——, and Van Slyke, L. L.: The casein of goat's milk. J. Biol. Chem. *24:* 173–175, 1916.

e. ——, ——: The soluble and insoluble compounds of goat's milk. J. Biol. Chem. *24:* 177–185, 1916.

f. ——, ——: A comparison of the composition of cow's milk, goat's milk, and human milk. J. Biol. Chem. *24:* 187–189, 1916.

21. Brand, E., Saidel, L. J., Goldwater, W. H., Kassell, B., and Ryan, F. J.: The empirical formula of beta-lactoglobulin. J. Am. Chem. Soc. *67:* 1524–1532, 1945.

22. Broek, A., and Wolff, L. K.: *Chem. Abst. 31:* 3162. The quantity of copper, zinc, and manganese in cow milk. Acta Brevia Neerland. Physiol., Pharmacol., Microbiol. *5:* 80–81, 1935.

23. Brown, J. B., and Orians, B. M.: The fatty acids of human milk fat. Arch. Biochem. *9:* 201–219, 1946.

24. Brown, W. R., Petersen, W. E., and Gortner, R. A.: A study of variations in the lactose content of milk. J. Dairy Science *19:* 81–92, 1936.

25. Burhans, C. W., and Smith, D. N.: Inorganic constituents of human milk in particular reference to racial variations. Am. J. Dis. Child. *26:* 304–308, 1923.

26. Burow (1900): *In:* Hess, A. F., and Helman, F. D. (85a).

27. Burow, R. (1905): *In:* Melander, O. (139).

28. Casini, A.: *Chem. Abst. 41:* 3878. The bromine content of cow milk. Ann. chim. applicata *36:* 219–221, 1946.

29. Castellanos, A. O., and Lizarralde, A.: The chemical composition of colostrum. Rev. asoc. argentina dietol. *1:* 199–202, 1943.

30. Caulfield, W. J., and Riddell, W. H.: The chloride content of cow milk. Cornell Veterinarian *25:* 334–344, 1935.

31. Chakraborty, R. K.: The vitamin C content of some Indian food-materials. Indian J. Med. Research *23:* 347–351, 1935–36.

32. Chibnall, A. C., Rees, M. W., and Williams, E. F.: The dicarboxylic and basic amino-acids of edestin, egg albumin and *b*-lactoglobulin. Biochem. J. *37:* 372–388, 1943.

33. Chittenden, R. H., and Painter, H. M.: *In:* Mellander, O. (139).

34. Coccheri, P.: *In:* Nataf, B., Mickelsen, O., Keys, A., and Petersen, W. E. (146).

35. Cole, L. J., and Johansson, I.: Yield and composition of milk from Aberdeen-Angus cows. J. Dairy Science *16:* 565–580, 1930.

36. Correns, A. E.: *In:* Munks, B., Robinson, A., Williams, H. H., and Macy, I. G. (143).

37. Courtney, A. M., and Brown, A.: *In:* Associates of Rogers (8).

38. Crowther, C., and Raistrick, H.: A comparative study of the proteins of the colostrum and milk of the cow and their relation to serum protein. Biochem. J. *10:* 434–451, 1916.

39. Dahlberg, A. C., and Carpenter, D. C.: The influence of method of sterilizing equipment upon development of oxidized flavors in milk. J. Dairy Science *19:* 541–551, 1936.

40a. Dam, H.: The cholesterol content of milk in relation to alimentary cholesterol. Z. physiol. chem. *224:* 127–128, 1934.

b. ——, Glavind, J., Larsen, E. H., and Plum, P.: Investigations into the cause of the physiological hypoprothrombinemia in newborn children. IV. The vitamin K content of woman's milk and cow's milk. Acta Med. Scand. *112:* 210–216, 1942.

c. ——: *In:* Nataf, B., Mickelsen, O., Keys, A., and Petersen, W. E. (146).

41. Daniel, L., and Norris, L. C.: Riboflavin content of milk and milk products. Food Research *9:* 312–318, 1944.

42. Dann, W. J.: The transmission of vitamin A from parents to young in mammals. II. The carotene and vitamin A content of cow's colostrum. Biochem. J. *27:* 1998–2005, 1933.

43. Davidson, L. S. P., and Leitch, I.: The nutritional anaemias of man and animals. Nutrition Abst. Rev. *3:* 901–930, 1934.

44a. Davies, W. L.: Observations on the copper and iron contents of milk and other dairy products. J. Dairy Research *3:* 86–92, 1931–32.

b. ——: The distribution of nitrogen in milk with reference to the solids-not-fat content. J. Dairy Research *4:* 142–146, 1932.

c. ——: Investigations on the milk of a typical herd of shorthorn cows. III. Nitrogen distribubution, chloride, lactose, copper and iron content over a period of 2 years. J. Dairy Research *6:* 363–368, 1935.

45. Deem, H. E.: Observations on the milk of New Zealand women. Arch. Dis. Childhood *6:* 53–70, 1931.

46a. Denis, W., and Minot, A. S.: Cholesterol in milk. J. Biol. Chem. *36:* 59–61, 1918.

b. ——, ——: Methods for the quantitative determination of the non-protein nitrogenous constituents of milk. J. Biol. Chem. *37:* 353–366, 1919.

47. Dhingra, D. R.: The component fatty acids and glycerides of the milk fats of Indian goats and sheep. Biochem. J. *27:* 851–859, 1933.

48. Dingle, H., and Sheldon, J. H.: A spectrographic examination of the mineral content of human and other milk. Biochem. J. *32:* 1078–1086, 1938.

49. Drea, W. F.: Spectrum analysis for trace elements in the ashes of human, goat and cow milk. J. Nutrition *16:* 325–331, 1938.

50. Drummond, J. C., Coward, K. H., and Watson, A. F.: Researches on vitamin A. VII. Notes on the factors influencing the value of milk and butter as sources of vitamin A. Biochem. J. *15:* 540–552, 1921.

51. Duggan, R. E.: Determination of free tryptophane in milk, cream and butter. J. Assoc. Offic. Agr. Chemists *31:* 151–163, 1948.

52a. Eckles, C. H., Combs, W. B., and Macy, H.: Milk and milk products, Third edition. McGraw-Hill Book Company, Inc., 1943.

b. ——, AND SHAW, R. H.: The influence of the stage of lactation on the composition and properties of milk. U. S. D. A. Bull. 155, 1913.

53. Editorial: Endemic goiter and iodine content of water, milk and pasture. J. Am. Med. Assoc. *108:* 729–730, 1937.

54. ELLENBERGER (1902). *In:* HESS, A. F., AND HELMAN, F. D. (85a).

55. ELMER, A. W., AND RYCHLIK, W.: Elimination of iodine in human colostrum and milk after childbirth. Compt. rend. soc. biol. *117:* 530–532, 1934.

56. ELSDON, G. D.: The composition of human milk. Analyst *53:* 78–82, 1928.

57. ENGEL, H., AND SCHLAG, H.: The colostrum of the cow. Milchw. Forsch. *2:* 1–15, 1924.

58. ENGEL, R. W.: The choline content of animal and plant products. J. Nutrition *25:* 441–446, 1943.

59a. ESCUDERO, P., AND PIERANGELI, E.: Influence of diet during pregnancy on the mineral and vitamin contents of colostrum. Rev. asoc. argentina dietol. *1:* 85–94, 1943.

b. ——, AND ESPEJO SOLA, J.: Comparative study of human and cow colostrum. Rev. asoc. argentina dietol. *1:* 203–209, 1943.

c. ——, AND WAISMAN, S. G.: *Chem. Abst. 41:* 5644. Comparative study of the protein and non-protein nitrogen of human and cow's milk. Bol. soc. quim. Peru *12:* 152–158, 1946.

60. ESCUDERO, A., HERRAIZ, M. L., AND ALVAREZ HERRERO, H. G. DE: Influence of boiling of milk on the thiamine, riboflavin, and nicotinic acid content. Rev. asoc. argentina dietol. *1:* 119–121, 1943.

61. EUGLING, W.: Thatigkeit landu-chem. Vers-Sta. Lander Vorarlberg 40, 1875–6.

62. EVANS, R. J., AND PHILLIPS, P. H.: The fluorine content of various fractions of milk and commercial caseins. J. Dairy Science *22:* 621–622, 1939.

63. FOLIN, O., DENIS, W., AND MINOT, A. S.: Lactose, fat, and protein in milk of various animals. J. Biol. Chem. *37:* 349–352, 1919.

64a. FORBES, E. B.: *In:* MITCHELL, H. H., AND MCCLURE, F. J. (140).

b. ——, BEEGLE, F. M., FRITZ, C. M., MORGAN, L. E., AND RHUE, S. N.: *In:* MITCHELL, H. H., AND MCCLURE, F. J. (140).

——, HALVERSON, J. O., AND MORGAN, L. E.: *In:* MITCHELL, H. H., AND MCCLURE, F. J. (140).

——, AND BEEGLE, F. M.: *In:* MITCHELL, H. H., AND MCCLURE, F. J. (140).

—— SCHULZ, J. A., HUNT, C. H., WINTER, A. R., AND REMLER, R. F.: *In:* MITCHELL, H. H., AND MCCLURE, F. J. (140).

65. FOSTER, G. L.: Some amino acid analyses of hemoglobin and b-lactoglobulin. J. Biol. Chem. *159:* 431–438, 1945.

66. FOX, F. W., AND GARDNER, J. A.: The cholesterol content of human milk. Biochem. J. *18:* 127–135, 1924.

67. FRAHM, J.: *In:* Associates of ROGERS (8).

68. GAMBLE, J. A., ELLIS, N. R., AND BESLEY, A. K.: Composition and properties of goat's milk as compared with cow's milk. U. S. D. A. Tech. Bull. 671, 1939.

69. GARDNER, J. A., AND FOX, F. W.: *In:* Associates of ROGERS (8).

70. GARRETT: *In:* MITCHELL, H. H., AND MCCLURE, F. J. (140).

71. GLIKIN (1909). *In:* HESS, A. F., AND HELMAN, F. D. (85a).

72. GRAHAM, W. R., JR., AND KAY, H. D.: Phosphorus compounds in milk. V. The phosphorus partition in milk with preliminary observations on milk phosphatase. J. Dairy Research *5:* 54–62, 1933–34.

73. GUNNESS, M., DWYER, I. M., AND STOKES, J. L.: Microbiological methods for the determination of amino acids. III. Extension of the uniform assay method for the ten essential amino acids to include tyrosine. J. Biol. Chem. *163:* 159–168, 1946.

74a. HAAS, J. H. DE, AND MEULEMANS, O.: *Chem. Abst.* 31: 443. The ascorbic acid (vitamin C) content of human milk in Batavia. Geneeskind. Tijdschr. Nederland. Indie *76:* 2277–2296, 1936.

b. ——, ——: The carotene and vitamin A content of cow milk and of cow milk mixtures: a contribution to vitamin A prophylaxis. Z. Vitaminforsch. *7:* 1–10, 1938.

75. HALLIDAY, N., AND DEUEL, H., JR.: The presence of free and combined thiamine in milk. J. Biol. Chem. *140:* 555–561, 1941.

76. Hammarsten, O.: *In:* Mellander, O. (139).

77. Hammett, F. S.: Variations in the composition of human milk during the first eleven days after parturition. J. Biol. Chem. *29:* 381–390, 1917.

78. Hand, D. B., and Sharp, P. F.: The riboflavin content of cow's milk. J. Dairy Science *22:* 779–783, 1939.

79. Hansen, R. G., Phillips, P. H., and Smith, V. R.: Colostrum milk and its vitamin A content. J. Dairy Science *29:* 809–814, 1946.

80. Harris, L. J., and Ray, S. N.: Diagnosis of vitamin C—subnutrition by urine analysis. Lancet *1:* 71–77, 1935.

81. Harris, R. S., and Bunker, J. W.: Vitamin D potency of human breast milk. Am. J. Public Health *29:* 744–747, 1939.

82. Henderson, L. M., and Snell, E. E.: A uniform medium for determination of amino acids with various microorganisms. J. Biol. Chem. *172:* 15–29, 1948.

83. Henry, K. M., Houston, J., and Kon, S. K.: The vitamin A and carotene contents of shorthorn colostrum. J. Dairy Research *11:* 1–8, 1940.

84. Herraiz, M., and Alvarez Herrero, H. G. de: Vitamin content of human colostrum. Rev. asoc. argentina dietol. *1:* 95–98, 1943.

85a. Hess, A. F., and Helman, F. D.: The phosphatide and total phosphorus content of woman's and cow's milk. J. Biol. Chem. *64:* 781–796, 1925.

b. ——, Supplee, G. C., and Bellis, B.: Copper as a constituent in woman's and cow's milk. Its absorption and excretion. J. Biol. Chem. *57:* 725–729, 1923.

86. Hier, S. W., Graham, C. E., Freides, R., and Klein, D.: The microbiological determination of amino acids in animal proteins. J. Biol. Chem. *161:* 705–716, 1945.

87a. Hilditch, T. P., and Jasperson, H.: The influence of dietary fat of varying unsaturation on the component acids of cow milk fats. Biochem. J. *37:* 238–243, 1943.

b. ——, ——: The component acids of milk fats of the goat, ewe, and mare. Biochem. J. *38:* 443–447, 1944.

c. ——, and Longenecker, H.: Further determination and characterization of the component acids of butter fat. J. Biol. Chem. *122:* 497–505, 1937–38.

d. ——, and Meara, M. L.: Human milk fat. I. Component fatty acids. Biochem. J. *38:* 29–34, 1944.

88. Hodges, M. A., and Peterson, W. H.: Manganese, copper, and iron content of serving portions of common foods. J. Am. Dietet. Assoc. *7:* 6–16, 1931.

89a. Hodson, A. Z.: The pyridoxine content of fresh, pasteurized, evaporated, and dried milk. J. Nutrition *27:* 415–418, 1944.

b. ——: The nicotinic acid, pantothenic acid, choline and biotin content of fresh, irradiated evaporated and dry milk. J. Nutrition *29:* 137–142, 1945.

c. ——, and Krueger, G. M.: Essential amino acid content of casein and fresh and processed cow's milk as determined microbiologically on hydrolyzates. Arch. Biochem. *10:* 55–64, 1946.

90a. Holmes, A. D., Jones, C. P., and Wertz, A. W.: Ascorbic acid, riboflavin and thiamine content of cow's milk; influence of ration. Am. J. Dis. Child. *67:* 376–381, 1944.

b. ——, ——, ——, Esselen, K., and McKey, B. V.: The ratio of ascorbic, nicotinic and pantothenic acids, riboflavin and thiamine in late summer milk. J. Dairy Science *27:* 849–855, 1944.

c. ——, Kuzmeski, J. W., Lindquist, H. G., and Rodman, H. B.: Goat milk as a source of bone-building minerals for infant feeding. Am. J. Dis. Child. *71:* 647–653, 1946.

d. ——, Lindquist, H. G., and Greenwood, E. K.: Variation in fat, ascorbic acid, and riboflavin content of goat's milk. J. Dairy Science *28:* 853–858, 1945.

e. ——, ——, Jones, C. P., Wertz, A. W., Esselen, K., McKey, B. V., and Fuller, E.: The vitamin content of commercial winter goat's milk. New England J. Med. *232:* 72–76, 1945.

f. ——, Tripp, F., Woelffer, E. A., and Satterfield, G. H.: Relation of volume of daily milk production to ascorbic acid content of cow's milk. Food Research *7:* 111–117, 1942.

91. Holt, L. E., Courtney, A. M., and Fales, H. L.: A theoretical study of women's milk, especially its inorganic constituents. Am. J. Dis. Child. *10:* 229–248, 1915.

2. Horn, M. J., Jones, D. B., and Blum, A. E.: Microbiological determination of valine in proteins and foods. J. Biol. Chem. *170:* 719–723, 1947.
93. Horrall, B. E.: Study of the lecithin content of milk and its products. Ind. (Purdue) Agric. Exp. Station Bull. 401, 1935.
94. Houston, J., Kon, S. K., and Thompson, S. Y.: The vitamin B_1 and riboflavin of milk: 3. Effect of stage of lactation and of season on the vitamin B_1 and riboflavin. J. Dairy Research *11:* 155–167, 1940.
95. Hove, E., Elvehjem, C. A., and Hart, E. B.: Boron in animal nutrition. Am. J. Physiol. *127:* 689–701, 1939.
96. Howe, P. E.: The differential precipitation of the proteins of colostrum and a method for the determination of the proteins in colostrum. J. Biol. Chem. *52:* 51–68, 1922.
97. Hrubetz, M. C., Deuel, H. J., Jr., and Hanley, B. J.: Studies on carotenoid metabolism. V. The effect of a high vitamin A intake on the composition of human milk. J. Nutrition *29:* 245–254, 1945.
98. Hunt, C. H., Winter, A. R., Schultz, J. A., and Miller, R. C.: *In:* Mitchell, H. H., and McClure, F. J. (140).
99. Ingalls, T. H., Draper, R., and Teel, H. M.: Vitamin C in human pregnancy and lactation. II. Studies during lactation. Am. J. Dis. Children *56:* 1011–1019, 1938.
100. Jeans, P. C., Marriott, W. M.: Infant Nutrition, 4th Ed. C. V. Mosby Company, 1947.
101. Jerlov, E.: *Chem. Abst. 26:* 3549. Citric acid in human milk. Svenska Lakartid. 17, 1929.
102. Johnson, P., Maynard, L. A., and Loosli, J. K.: The riboflavin content of milk as influenced by diet. J. Dairy Science *24:* 57–64, 1941.
103. Johnston, F. A.: Iron content of market milk. Food Research *9:* 212–217, 1944.
104. Jones, T. S. G., and Davies, W. L.: The relation of sodium to chlorine in the milk of Shorthorn and Guernsey cows. Biochem. J. *29:* 978–981, 1935.
105. Kahare, E., and Levy, J.: *Chem. Abst. 40:* 5122. Biochemistry of choline and its derivatives. XIII. Choline compounds of milk. Boll. soc. chim. biol. *27:* 72–77, 1945.
106. Kahlenberg, O. J., and Voris, L.: The percentage of fat as a basis for estimating the composition of milk. J. Agric. Research *43:* 749–755, 1931.
107. Kasahara, M., and Nosu, S.: *Chem. Abst. 29:* 8085. The so-called "normal lead in human milk." Jahrb. Kinderheilk. *145:* 78–80, 1935.
108. Keller, A., and Mai, H.: Composition of milk. I. Significance of the chlorine-sugar value for distinguishing between human and cow milk. Schweiz. med. Woch. *60:* 487–489, 1930.
109. Kemmerer, A. R., and Todd, W. R.: The effect of diet on the manganese content of milk. J. Biol. Chem. *94:* 317–321, 1931.
110. Kendall, N.: Thiamine content of various milks. J. Pediat. *20:* 65–73, 1942.
111. Keston, A. S., Udenfriend, S., and Cannan, R. K.: A method for the determination of organic compounds in the form of isotopic derivatives. I. Estimation of amino acids by the carrier technique. J. Am. Chem. Soc. *71:* 249–257, 1949.
112. Knott, E. M., Kleiger, S. C., and Bracamonte-Torres, F.: Factors affecting the thiamine content of breast milk. J. Nutrition *25:* 49–58, 1943.
113. Koch, W., and Woods, H. S.: The quantitative estimation of the lecithins. J. Biol. Chem. *1:* 203–211, 1905–06.
114. Kodicek, E., and Wang, Y. L.: The fluorimetric estimation of riboflavin in foodstuffs and other biological material. Biochem. J. *44:* 340–348, 1949.
115. Koga, A.: *Chem. Abst. 28:* 7334. Zinc content of human milk, and of milk of the cow and horse at different periods of lactation. Keijo J. Med. *5:* 106–110, 1934.
116. Konig.: *In:* Leach, A. E. (126).
117. Kon, S. K., and Watson, M. B.: Vitamin C content of cow's milk. Biochem. J. *31:* 223–226, 1937.
118. Kondo, K., and Mori, S.: Milk. II. Mineral constituents of goat milk. J. Chem. Soc. Japan *53:* 1163–1168, 1932.
119. Kopaczewski, W.: The surface tension of milk. Lait *16:* 356–359, 1936.
120a. Kramer, M. M., Bair, M. D., Kunerth, B. L., and Riddell, W. H.: The vitamin A value of colostrum and milk of four cows determined by the single-feeding method. J. Agric. Research *56:* 227–232, 1938.

b. ——, Dickman, R. M., Hildreth, M. D., Kunerth, B. L., and Riddell, W. H.: Riboflavin value of milk. J. Dairy Science *22:* 753–759, 1939.

c. ——, Gardner, I., Kunerth, B. L., and Riddell, W. H.: Vitamin G (riboflavin) content of colostrum and milk of cows determined biologically. J. Agric. Research *56:* 233–237, 1938.

121. Krauss, W. E., and Washburn, R. G.: The iron and copper content of milk throughout the season as related to anemia development in rats. J. Biol. Chem. *114:* 247–252, 1936.

122. Lampert, L. M.: The freezing point of milk. J. Assoc. Official Agric. Chem. *22:* 768–771, 1939.

123. Lang, K.: The composition of goat milk protein. Milchw. Forsch. *16:* 180–182, 1933.

124a. Langstein, L., and Bergell, P.: *In:* Mellander, O. (139).

b. ——, and Edelstein, F.: *In:* Mellander, O. (139).

125a. Lawrence, J. M., Herrington, B. L., Maynard, L. A.: Human milk studies. XXVII. Comparative values of bovine and human milks in infant feeding. Am. J. Dis. Child. *70:* 193–199, 1945.

b. ——, ——, ——: The nicotinic acid, biotin and pantothenic acid content of cow's milk. J. Nutrition *32:* 73–91, 1946.

126. Leach, A. E.: Food inspection and analysis, Fourth edition. John Wiley & Sons, Philadelphia, 1920.

127. Lehmann, J., and Hempel, W.: *In:* Mellander, O. (139).

128. Leone, A., and Cadeddu, E.: *Chem. Abst. 39:* 2548. The amount of bromine in the child's body under physiologic conditions. Riv. clin. pediat. *38:* 257–283, 1940.

129. Leulier, A., Revol, L., and Paccard, R.: Potassium content of normal human milk. Compt. rend. soc. biol. *124:* 1114–1115, 1937.

130. McDowall, F. H., Bathurst, N. O., and Campbell, I. L.: *Chem. Abst. 41:* 6636. The thiamine, riboflavin and niacin content of some New Zealand milks. New Zealand J. Sci. Technol. *28a:* 316–328, 1947.

131. McMahan, J. R., and Snell, E. E.: The microbiological determination of amino acids. I. Valine and arginine. J. Biol. Chem. *152:* 83–95, 1944.

132a. Macy, I. G.: The composition of human colostrum and milk. Am. J. Dis. Children *78:* 589, 1949.

b. ——: Unpublished data.

133. Makris, C.: *In:* Mellander, O. (139).

134. Mandel, P., and Bieth, R.: *Chem. Abst. 42:* 7893. Nucleic acid in milk. Compt. rend. soc. biol. *142:* 234–235, 1948.

135. Matthews, N. L., Curtis, G. M., and Meyer, J. H.: The effect of increased iodine feeding upon the iodine content of cow's milk. J. Dairy Research *10:* 395–402, 1939.

136. Maurer, E., and Diez, S.: The occurrence of iodine in the human and animal organisms. Munch. med. Wochschr. *73:* 17–20, 1926.

137. Maynard, L. A.: Unpublished data.

138. Meigs, E. B., and Marsh, H. L.: The comparative composition of human milk and of cow's milk. J. Biol. Chem. *16:* 147–168, 1913–14.

139. Mellander, O.: On chemical and nutritional differences between casein from human and from cow's milk. Upsala Lakareforenings forhandlingar *52:* 107–198, 1947.

140. Mitchell, H. H., and McClure, F. J.: Mineral nutrition of farm animals. Natl. Res. Council Bull. 99, 1937.

141. Morgan, A. F., and Haynes, E. G.: Vitamin B_1 content of human milk as affected by ingestion of thiamin chloride. J. Nutrition *18:* 105–114, 1939.

142. Muhlbock, O.: *Chem. Abst. 29:* 4056. Cholesterol content of human milk. Z. Kinderheilk. *56:* 303–306, 1934.

143. Munks, B., Robinson, A., Williams, H. H., and Macy, I. G.: Human milk studies. XXV. Ascorbic acid and dehydroascorbic acid in colostrum and mature human milk. Am. J. Dis. Child. *70:* 176–181, 1945.

144. Myers, B.: An investigation on the analysis of human milk. Brit. J. Children's Diseases *24:* 249–257, 1927.

145. Nakanishi, H.: *In:* Nataf, B., Mickelsen, O., Keys, A., and Petersen, W. E. (146).

146. Nataf, B., Mickelsen, O., Keys, A., and Petersen, W. E.: The cholesterol content of cows' milk. J. Nutrition *36:* 495–506, 1948.

147. Nerking and Haensel (1908). *In:* Hess, A. F., and Helman, F. D. (85a).

148a. Neuweiler, W.: *In:* Roderuck, C. E., Williams, H. H., and Macy, I. G. (171b).

b. ——: *Chem. Abst: 41:* 5188. The content of nicotinic acid in human milk; the influence of administration of nicotinic acid. Z. Vitaminforsch. *15:* 193–197, 1944.

c. ——: VitaminE in woman's milk. Intern. Z. Vitaminforsch. *20:* 108–116, 1948.

149. Overman, O. R., Sanmann, F. P., and Wright, K. E.: *In:* Associates of Rogers, L. A. (8).

150. Palmer, A. H.: The preparation of a crystalline globulin from the albumin fraction of cow's milk. J. Biol. Chem. *104:* 359–372, 1934.

151. Pearson, P. B., and Darnell, A. L.: The thiamine, riboflavin, nicotinic acid and pantothenic acid content of colostrum and milk of the cow and ewe. J. Nutrition *31:* 51–57, 1946.

152. Peterson, V. E., and Turner, G. W.: The energy content of goat milk. J. Nutrition *17:* 293–301, 1939.

153. Plimmer, R. H. A., and Lowndes, J.: Analysis of proteins. IX. The content in amino-acids of the caseinogen and lactalbumin of woman's milk. Biochem. J. *31:* 1751–1757, 1937.

154. Polonovski, M., Cuvelier, L., and Avenard, R.: The lipides of human milk. Compt. rend. soc. biol. *111:* 6–7, 1932.

155. Polskin, L. J., Kramer, B., and Sobel, A. E.: Secretion of vitamin D in milks of women fed fish liver oil. J. Nutrition *30:* 451–466, 1945.

156a. Quaife, M. L.: Tocopherols (vitamin E) in milk: their chemical determination and occurrence in human milk. J. Biol. Chem. *169:* 513–514, 1947.

b. ——: Personal communication.

157. Quam, G. N., and Hellwig, A.: The copper content of milk. J. Biol. Chem. *78:* 681–684, 1928.

158. Ramsdell, G. A., and Whittier, E. O.: Composition of casein in milk. J. Biol. Chem. *154:* 413–419, 1944.

159. Randoin, L., and Raffy, A.: *In:* Roderuck, C. E., Coryell, M. N., Williams, H. H., and Macy, I. G. (171a).

160. Rangappa, K. S.: Cryoscopy and refraction in milk. Biochim. et Biophys. Acta *2:* 207–209, 1948.

161. Rasmussen, R., Guerrant, N. B., Shaw, A. O., Welch, R. C., and Bechdel, S. I.: The effects of breed characteristics and stages of lactation on the vitamin C (ascorbic acid) content of cow's milk. J. Nutrition *11:* 425–432, 1936.

162. Rauschning, S.: The composition of the casein of goat milk. Milchw. Forsch. *15:* 390–401, 1933.

163. Rees, M. W.: The estimation of threonine and serine in proteins. Biochem. J. *40:* 632–640, 1946.

164. Reis, F., and Chakmakjian, H. H.: Determination of iron in cow and human milk. J. Biol. Chem. *98:* 237–240, 1932.

165. Remington, R. E., and Supplee, G. C.: Studies on the iodine content of milk. II. Variations in the mixed milk of herds. J. Dairy Science *17:* 19–28, 1934.

166. Revol, L., and Paccard, A.: *Chem. Abst. 32:* 225. Total sulfur of human and cow milk. Compt. rend. soc. biol. *126:* 25–26, 1937.

167. Richmond, M. S., Satterfield, G. H., Grinnells, C. D., and Dann, W. J.: Ascorbic acid content of goat's milk and blood; influence of ascorbic acid injection and diet. J. Nutrition *20:* 99–108, 1940.

168. Richmond (1914): *In:* Leach, A. E. (126).

169. Riemenschneider, R. W., and Ellis, N. R.: The component fat acids of goat-milk fat. J. Biol. Chem. *113:* 219–233, 1936.

170. Ritchie, B. V.: The calcium and phosphorus content of milk from Australian women. Med. J. Australia *1:* 331–336, 1942.

171a. Roderuck, C. E., Coryell, M. N., Williams, H. H., and Macy, I. G.: Human Milk Studies. XXIV. Free and total riboflavin contents of colostrum and mature human milk. Am. J. Dis. Child. *70:* 171–175, 1945.

b. ——, Williams, H. H., and Macy, I. G.: Human Milk Studies. XXIII. Free and total thiamine content of colostrum and mature human milk. Am. J. Dis. Child. *70:* 162–170, 1945.

Rogers, L. A. See Associates of Rogers (8).

172. Roller, P. E.: A study of breast milk fat. J. Pediat. *4:* 238–241, 1934.

173. Rowland, S. J.: The protein distribution in normal and abnormal milk. J. Dairy Research *9:* 47–57, 1938.

174. Ruegamer, W. R., Michaud, L., and Elvehjem, C. A.: A simplified method for the determination of iron in milk. J. Biol. Chem. *158:* 573–579, 1945.

175. Ryan, F. J., and Brand, E.: A method for the determination of leucine in protein hydrolysates and in foodstuffs by the use of a neurospora mutant. J. Biol. Chem. *154:* 161–175, 1944.

176. Sadovsky, A., Weber, D., and Wertheimer, E.: The concentration of vitamin C in blood during and after pregnancy. J. Lab. Clin. Med. *25:* 120–131, 1939.

177. Sandelin, A. E.: *In:* Mellander, O. (139).

178a. Sato, M., and Murata, K.: *Chem. Abst. 26:* 1354. Zinc content of milk and method of estimation. Trans. Tottori Soc. Agric. Science *2:* 206–223, 1931.

b. ——, ——: *Chem. Abst. 29:* 6557. Microcolorimetric determination of magnesium in milk. J. Agric. Chem. Soc. (Japan) *11:* 431–434, 1935.

179. Schlossman (1897). *In:* Hess, A. F., and Helman, F. D. (85a).

180. Selleg, I., and King, C. G.: The vitamin C content of human milk and its variation with diet. J. Nutrition *11:* 599–605, 1936.

181. Semb, J., Baumann, C. A., and Steenbock, H.: Fat-soluble vitamins. XLI. The carotene and vitamin A content of colostrum. J. Biol. Chem. *107:* 697–703, 1934.

182. Seshan, P. A., and Sen, K. C.: Studies on carotene in relation to animal nutrition. IV. Carotene-balance experiments with cows and bullocks. J. Agric. Science *32:* 286–293, 1942.

183. Sheldon, J. H., and Ramage, H.: Rubidium in milk. Biochem. J. *25:* 1608–1627, 1931.

184. Shohl, A. T.: Mineral Metabolism. Reinhold Publishing Co., New York, 1939.

185. Shope, R. E., and Gowen, J. W.: Cholesterol and cholesterol ester content of bovine colostrum. J. Exper. Medicine *48:* 21–24, 1928.

186. Sisson, W. R., and Denis, W.: Studies on the inorganic constituents of milk. 1. Chloride in human milk. Am. J. Dis. Child. *21:* 389–400, 1921.

187. Slater, E. C., and Rial, E. J.: *In:* Roderuck, C. E., Williams, H. H., and Macy, I. G. (171b).

188a. Smith, E. L.: The immune proteins of bovine colostrum and plasma. J. Biol. Chem. *164:* 345–358, 1946.

b. ——, and Greene, R. D.: The isoleucine content of seed globulins and b-lactoglobulin. J. Biol. Chem. *172:* 111–112, 1948.

189a. Sommer, H. H.: Acidity of milk and dairy products. Wis. Agric. Exp. Station Research Bull. 127, 1935.

b. ——, and Hart, E. B.: The heat coagulation of milk. J. Biol. Chem. *40:* 137–151, 1919.

190. Spinelli, F.: *Chem. Abst. 40:* 7320. Indican content of cow's and goat's milk. Boll. soc. ital. biol. sper. *21:* 211–212, 1946.

191. Stearns, G.: Personal communication.

192. Stefaniak, J. J., and Peterson, W. R.: *Chem. Abst. 41:* 5644. The pantothenic acid, niacin, and biotin contents of commercial and experimental milks. J. Dairy Science *29:* 783–788, 1946.

193a. Stein, W. H., and Moore, S.: Chromatography of amino acids on starch columns. Separation of phenylalanine, leucine, isoleucine, methionine, tyrosine, and valine. J. Biol. Chem. *176:* 337–365, 1948.

b. ——, ——: Amino acid composition of b-lactoglobulin and bovine serum albumin. J. Biol. Chem. *178:* 79–91, 1949.

194. Stewart, J., and McCallum, J. W.: The vitamin A content of the colostrum of dairy cows. J. Agric. Science *28:* 428–436, 1938.

195. Stokes, J. L., Gunness, M., Dwyer, I. M., and Caswell, M. C.: Microbiological methods for the determination of amino acids. II. A uniform assay for the ten essential amino acids. J. Biol. Chem. *160:* 35–49, 1945.

196. Stoklasa (1897): *In:* Hess, A. F., and Helman, F. D. (85a).

197. Stubbs, J. R.: Examination of one thousand milks by the Hortwet freezing-point process. Analyst *59:* 146–152, 1934.

198. Stugart, R.: Determination of iron in milk and other biological materials. Ind. Eng. Chem. (Analyt. Ed.), *3:* 390–393, 1931.

199. Sundararajan, A. R.: *In:* Roderuck, C. E., Williams, H. H., and Macy, I. G. (171a).

200. Sundberg, T.: *Chem. Abst. 26:* 219. Correlation between sugar, chlorine, and refractive index. Svensk. Kem. Tids. *43:* 198–202, 1931.

201. Supplee, G. C., and Bellis, B.: The copper content of cow milk. J. Dairy Science *5:* 455–467, 1922.

202a. Sutton, T. S., and Esh, G. C.: The nutrition of the new born calf. I. Changes in the tryptophan content of the blood plasma following birth and the ingestion of the colostrum. J. Dairy Science *31:* 183–187, 1948.

b. ——, Warner, R. G., and Kaeser, H. E.: The concentration and output of carotenoid pigments, vitamin A, and riboflavin in the colostrum and milk of dairy cows. J. Dairy Science *30:* 927–932, 1947.

203. Sydow, G. V.: Variations in the fat content of collected human milk. Acta Paediat. *32:* 756, 1945.

204. Sylvester, N. D., and Lampitt, L. H.: Determination of copper in foods with special reference to milk. Analyst *60:* 376–382, 1935.

205. Tangl, F.: *In:* Mellander, O. (139).

206. Theophilus, D. R., and Stamberg, O. E.: Influence of breed, feed and processing on the riboflavin content of milk. J. Dairy Science *28:* 259–268, 1945.

207. Tobey, E. R.: Analyses of dairy products, milk and cream. Maine Agric. Exp. Station Official Inspections Bull. 191, 1944.

208. Torrisi, D.: *In:* Nataf, B., Mickelsen, O., Keys, A., and Petersen, W. E. (146).

209. Toverud, K. U.: *In:* Roderuck, C. E., Williams, H. H., and Macy, I. G. (171b).

210. Tracy, A., and McPheat, J.: Spectrographic determination of lead in blood. Biochem. J. *37:* 683–686, 1944.

211. Trout, G. M.: The composition and properties of goats' milk. Michigan Agricultural Experiment Station Quarterly Bulletin *23:* 254–264, 1941.

212. Turner, R. G.: Iodine and thyroid hyperplasia. I. The iodine content of human skimmed milk from goitrous and non-goitrous regions. Am. J. Dis. Child. *48:* 1209–1227, 1934.

213. U. S. Dept. of Agriculture: Physiological Energy Values of Selected Food Items. Bureau of Human Nutrition and Home Economics Publ. FE644, 1948.

214a. Van Slyke, L. L., and Bosworth, A. W.: Method of preparing ash-free casein and paracasein. J. Biol. Chem. *14:* 203–206, 1913.

b. ——, ——: Chemical changes in the souring of milk. J. Biol. Chem. *24:* 191–202, 1916.

215a. Vickery, H. B.: The determination of arginine by means of flavianic acid. J. Biol. Chem. *132:* 325–342, 1940.

b. ——, and White, A.: The basic amino acids of casein. J. Biol. Chem. *103:* 413–415, 1933.

c. ——, and Winternitz, J. K.: The determination of histidine with the aid of 3,4-dichlorobenzenesulfonic acid. J. Biol. Chem. *156:* 211–229, 1944.

216. Voohries, E. C.: The milk goat in California. Cal. Agric. Exp. Station Bull. 285, 1921.

217. Wacker, L., and Beck, K. F.: Cholesterol content of human and cow milk. Z. Kinderheilk. *27:* 288–292, 1921.

218. Waller, H., Aschaffenburg, R., and Grant, M. W.: The viscosity, protein distribution, and 'gold number' of the antenatal and postnatal secretions of the human mammary gland. Biochem. J. *35:* 272–282, 1941.

219. White, W. B. (1928). *In:* Associates of Rogers (8).

220. Whitnah, C. H., and Riddell, W. H.: Variations in the vitamin C content of milk. J. Dairy Science *20:* 9–14, 1937.

221a. Widdows, S. T., and Lowenfeld, M. F.: A study of the composition of human milk. The influence of the method of extraction on the fat percentage. Biochem. J. *27:* 1400–1410, 1933.

b. ——, ——, Bond, M., Shiskin, C., and Taylor, E. I.: A study of the antenatal secretion of the human mammary gland and a comparison between this and the secretion obtained directly after birth. Biochem. J. *29:* 1145–1165, 1935.

c. ——, ——, ——, and Taylor, E. I.: A study of the composition of human milk in the later periods of lactation and a comparison with that of early milk. Biochem. J. *24:* 327–342, 1930.

222. Williams, R. J., Cheldelin, V. H., and Mitchell, H. K.: The B vitamin content of milk from animals of different species. Univ. Texas Publ. *4237:* 97–104, 1942.

223. Wiliamson, M. B.: Amino acid composition of human milk protein. J. Biol. Chem. *156:* 47–52, 1944.

224a. Winikoff, D.: Calcium, magnesium and phosphorus in the milk of Australian women. Med. J. Australia *31:* 660–664, 1944.

b. ——: Ascorbic acid in the milk of Melbourne women. Med. J. Australia *33:* 205–210, 1946.

225. Wright, N. C., and Papish, J.: The inorganic constituents of milk. Science *69:* 78, 1929.

226. Wroblewski, A.: *In:* Mellander, O. (139).

227. Zondek, S. G., and Bondmann, M.: *Chem. Abst. 26:* 184. Copper in human and cow milk. Klin. Wochschr. *10:* 1528–1530, 1931.

Added reference: Block, R. J., and Bolling, Diana: The quantities of amino acids in the nonprotein fraction of breast and cow's milk. Arch. Biochem. *25:* 350–353, 1950.

TABLES

TABLE 1

COMPILATION OF THE PROPERTIES AND COMPOSITION OF HUMAN COLOSTRUM, TRANSITIONAL AND MATURE MILK, MATURE GOAT MILK AND MATURE COW MILK

	HUMAN COLOSTRUM, 1–5 days					TRANSITIONAL MILK, 6–10 days					MATURE HUMAN MILK					MATURE GOAT MILK					MATURE COW MILK				
	Ref. no.	No. detm.	Mean	Min.	Max.	Ref. no.	No. detm.	Mean	Min.	Max.	Ref. no.	No. detm.	Mean	Min.	Max.	Ref. no.	No. detm.	Mean	Min.	Max.	Ref. no.	No. detm.	Mean	Min.	Max.
Physical Properties																									
ELECTRICAL CONDUCTIVITY																					119	12	0.0086		
GOLD NUMBER	218	10	2370	500	8000	218	6	792	500	1500															
FREEZING POINT, (°C.)																					7		0.546	0.529	0.560
																					122	1224	0.544	0.523	0.566
																					160	14	0.548	0.540	0.555
																					197	1000	0.544	0.529	0.563
INDEX OF REFRACTION											172		(at 40°C.)	1.4556	1.4583						4 (40°C.)	1	1.4538 (converted)		
																					52b (25°C.)	304		1.4531	1.4610
																					160 (40°C.)	14	1.3464	1.3458	1.3472
OSMOTIC PRESSURE																					200	70	196.4		
pH VALUE																90e	18	6.37			189a	386		6.22	6.77
																211	19		6.33	6.52					
REFRACTIVE CONSTANT																					160	14	0.2070	0.2065	0.2075
SPECIFIC GRAVITY	29		1.034			132a	2	1.035	1.034	1.036	132a	333	1.031	1.026	1.037	116	200	1.030	1.028	1.036	3	10	1.030		
											168	94	1.031	1.024	1.043	211	17	1.034	1.032	1.035	35	10	1.034	1.032	1.036
																216	50	1.034	1.031	1.037	116	800	1.032	1.026	1.037
																					207	1448	1.035	1.021	1.036
SURFACE TENSION (dynes/cm²)																68		52.0			68			51.1	51.5
																					119	12	52.8	51.7	55.0
VISCOSITY (at 15°)																					119	12	1.75		

Fat Characteristics

FAT MELTING POINT (°C.)						20b	32 (first 10 days)				23			26.	6.5						52b	484		17.57	52.90
											172			33.5	38.9										
HEHNER NUMBER																68			87.8	88.6	68			88.5	90.0
HUBL NUMBER																					35	10	35.2	30.3	39.3
IODINE NUMBER						20b	56.22 (first 10 days)				23		61.65			47		28.8			52b	474		23.80	49.44
						87d	(early lact.)		52.1	56	87d			48.2	54.7	68			30.3	32.5	68			37.2	42.5
						154	64.5 (early lact.)				172			46.6	50.3	87b		28.8			87a,c		38.4		
KIRSCHNER VALUE						87d	0.6 (early lact.)				87d		0.5			47		19.9			4		24.52		
																87b		15.6			87a		23.5		
POLENSKE NUMBER						20b	0.1 (first 10 days)				87d		1.2			47		8.2			68			2.2	2.8
						87d	1.2 (early lact.)									68			7.5	8.1	87a		1.5		
																87b		7.2							
REICHERT MEISEL NUMBER						20b	2.5 (first 10 days)				23		0.6			47		31.7			35	10	27.6	24.6	30.8
						87d	1.2 (early lact.)				87d		0.9			68			25.5	26.0	52b	485		6.10	33.38
											172			2.33	2.84	87b		23.2			68			25.6	28.6
																					87a		30.0		
SAPONIFICATION NUMBER						20b	205.1 (first 10 days)				23		204.7			47		238.1			52b	489		200.1	252.3
						87d	(early lact.)		274	277.2	87d			274.4	274.9	68			234.6	235.4	68			222.6	228.2
											172			196.2	202.0	87b		233.7			87a,c		248.0		
THIOCYANOGEN NUMBER																68			26.1	27.9	68			32.1	37.0

Chemical Components

CITRIC ACID (mg./100 ml.)											101			35	125	20c	4	151	131	171	189b	30	197	100	312
																					214b		237		
TITRATABLE ACIDITY (per cent lactic acid)																211	39	0.199			51	18	0.11	0.08	0.14
																					189b	86	0.178	0.102	0.26
INDICAN (mmg./100 ml.)*											2		30	0	298	190		192	30	272	190		124	28	220
ENERGY (CAL./100 ml.)																					106	134	68	57	85
	59a	9	49			132a	21	74	68	83	59b		71			152	18	86	53	114	132b	11	70	67	74
	132a	8	67	59	73						132a	438	75	45	119	213		70			213		68		
											144	184	67												

---

* mmg = micrograms.

TABLE 1—(*Continued*)

	HUMAN COLOSTRUM, 1–5 days					TRANSITIONAL MILK, 6–10 days					MATURE HUMAN MILK					MATURE GOAT MILK					MATURE COW MILK				
	Ref. no.	No. detm.	Mean	Min.	Max.	Ref. no.	No. detm.	Mean	Min.	Max.	Ref. no.	No. detm.	Mean	Min.	Max.	Ref. no.	No. detm.	Mean	Min.	Max.	Ref. no.	No. detm.	Mean	Min.	Max.
Chemical Components—(*Continued*)																									
TOTAL SOLIDS (gm./100 ml.)	91	2	12.8	12.7	12.9	91	2	13.9	12.8	15.0	91	27	12.2	9.8	15.6	98	6	12.5			35	10	13.6	13.0	15.1
	132a	29	12.8	10.0	16.7	132a	46	13.3	10.5	15.6	97	43	12.1			152	18	15.1	12.5	19.1	64a,b	187	12.2		
											132a	610	12.9	10.3	17.5	211	37	13.0	11.0	14.5	70	35	12.4		
																216	50	13.8	9.7	17.4	106	134	12.3	10.5	14.7
																					137	130	12.4	7.7	15.6
																					189b	30	13.4	9.8	15.2
																					207	1447	13.3	8.5	19.6
ASH COMPONENTS																									
ASH (gm./100 ml.)	12	68	0.30	0.24	0.36	12	68	0.25	0.18	0.35	45	30	0.22			52a		0.55			15	134	0.75		
	29		0.35			132a	16	0.27	0.23	0.34	69	1154	0.21			67	326	0.78			35	10	0.68	0.64	0.74
	59a	9	0.36			138	5	0.19	0.15	0.25	91	26	0.20	0.16	0.24	68		0.79			52a		0.65		
	132a	5	0.31	0.25	0.35	221b	95	0.26	0.14	0.42	97	43	0.20			116	200	0.76	0.39	1.06	64a,b	187	0.74		
	221b	105	0.35	0.20	0.72						132a	390	0.20	0.16	0.27	118	31	0.85	0.78	0.99	68			0.70	0.73
											168	94	0.20	0.09	0.50	211	17	0.92			70	35	0.73		
											221c	57	0.23			216	50	0.72	0.56	0.96	116	800	0.71	0.35	1.21
																					138	9	0.72	0.68	0.77
																					149	1998	0.72		
																					219	208	0.72		
MAJOR MINERAL CONSTITUENTS																									
CALCIUM (mg./100 ml.)	29		27			132a	46	46	23	63	20a		35			20e	4	138	114	163	15	134	112		
	59a	9	29			221b	100	30	18	49	25	55	28	15	40	68		114			20a		144		
	132a	28	48	24	66	224a	22	26	21	33	91	26	32	20	50	90c	27	137	112	164	64a,b	187	111		
	221b	115	28	14	49						132a	628	34	17	61	98	6	132			68			106	117
	224a	22	23	13	34						153	31	40	20	60	118	31	130	103	176	70	35	114		
											170	467		17	42						132b	116	137	56	381
											221c	53	38								153	6	140	133	150
											224a	584	28								189b	30	124	94	150

CHLORINE (mg./100 ml.)	29		88			91	2	50	30	69	25	44	50	16	158	20e	4	204	158	260	3	10	72		
	91	2	69	64	74	108	2	72	61	84	91	27	39	25	57	98	6	159			15	134	108		
	108	3	159	74	210	132a	21	46	30	72	108	10	34	30	40	118	31	115	56	168	30	1006	129	70	290
	132a	8	59	44	101	221b	126	48	17	116	132a	216	38	9	73						44b,c	158	98	72	203
	221b	186	78	20	233						186		53	18	112						64a,b	187	107		
																					70	35	80		
																					104	20	113	70	193
																					108		84		
																					132b	27	108	93	141
MAGNESIUM (ml./100 ml.)	29		3			132a	44	4	2	5	20a		3			20e	4	21	20	24	15	134	13		
	91	2	4	3	6	178b		3			91	25	5	3	6	90c	27	17	13	22	20a		13		
	132a	28	4	3	8	224a	22	4	3	5	132a	302	4	2	6	98	6	14			64a,b	187	13		
	224a	21	3	1	5						178b			2	2	118	31	13	10	18	70	35	10		
											224a	155	4								132b	113	13	7	22
																					178b			8	9
																					189b	30	14	11	17
PHOSPHORUS (mg./100 ml.)																19	14	98							
	29		15			132a	46	20	10	32	25	55	17	10	35	20e	4	95	84	121	3	9	120	107	129
	59a	9	13			221b	65	17	10	24	85a	7	16	12	19	68		98			15	134	95		
	132a	28	16	8	25	224a	22	15	13	18	91	27	14	9	22	90c	27	112	88	134	64a,b	187	93		
	221b	65	13	6	21						132a	628	14	7	27	98	6	97			68			88	101
	224a	21	14	10	18						153	31	16	11	24	118	31	118	90	157	70	35	99		
											170	467		7	21	152	13	122	92	161	72	18	104	84	126
											221c	59	18								85a	4	79	76	82
											224a	584	14								132b	89	91	56	112
																					153	6	101	97	106
																					189b	30	107	84	128
POTASSIUM (mg./100 ml.)	29		74			132a	25	64	53	77	20a		71			20e	4	193	166	228	15	134	139		
	132a	11	74	66	87						25	54	52	27	81	90c	27	170	106	242	64a,b	187	141		
											91	26	48	30	66	98	6	172			70	35	149		
											129	45	55	42	70	118	31	189	144	217	132b	115	143	38	287
											132a	18	51	37	64						214b		120		
SODIUM (mg./100 ml.)	29		47			132a	44	29	19	54	20a		15			20e	4	38	35	40	15	134	58		
	132a	28	50	26	136						91	26	13	2	25	98	6	42			64a,b	187	60		
											132a	302	17	6	44	118	31	42	19	60	70	35	40		
																					104	20	77	39	139
																					132b	114	57	31	214
																					214b		55		
SULFUR (mg./100 ml.)	29		20			132a	19	20	15	23	132a	116	14	5	30	98	6	29			64b	53	30		
	132a	8	23	20	26						166			8	20	118	31	3	2	4	132b	27	30	24	36
																					166			27	44

	HUMAN COLOSTRUM, 1-5 days					TRANSITIONAL MILK, 6-10 days					MATURE HUMAN MILK					MATURE GOAT MILK					MATURE COW MILK				
	Ref. no.	No. detm.	Mean	Min.	Max.	Ref. no.	No. detm.	Mean	Min.	Max.	Ref. no.	No. detm.	Mean	Min.	Max.	Ref. no.	No. detm.	Mean	Min.	Max.	Ref. no.	No. detm.	Mean	Min.	Max.
Chemical Components—(*Continued*)																									
MINOR MINERAL CONSTITUENTS																									
ALUMINUM (*mg./100 ml.*)											48	30	tr			49	4	tr			48	26	tr		
											49	6	tr								49	12	tr		
																					225		tr		
BARIUM (*mmg./100 ml.*)											48	30	tr			49	4	tr			18		tr		
											49	6	tr								48	26	tr		
																					49	12	tr		
BORON (*mg./100 ml.*)											48	30	tr			49	4	tr			18		tr		
											49	6	tr			95		0.0177			48	26	tr		
																					49	12	tr		
																					95	17	0.01558	0.0094	0.0228
																					225		tr		
BROMINE (*mmg./100 ml.*)											128	17	912	327	1502						28			18.4	24.1
CHROMIUM (*mg./liter*)											49	5	tr			49	4	tr			49	7	tr		
COBALT (*mmg./100 ml.*)																					6b		0.06		
COPPER (*mg./100 ml.*)	29		0.06								22		0.04			49	4	tr			22		0.003		
	59a	7	0.05								49	6	tr			68		0.05			39	6	0.02		
											85b	2	0.05	0.04	0.06	157	6	0.02	0.02	0.02	44a,c	24	0.04	0.02	0.40
											227			0.05	0.06						68			0.057	0.058
											59b		0.03								85b	1	0.055		
																					88		0.02		
																					121	20+	0.016	0.014	0.017
																					132b	11	0.07		
																					157	20	0.06	0.03	0.16
																					201	23	0.05	0.02	0.08
																					204	16	0.012	0.009	0.017
																					227			0.015	0.02

Copyrigl material

FLUORINE (mg./100 ml.)																				62		0.0204	0.01	0.028
																				191	3	0.0113	0.007	0.0138
IODINE (mmg./100 ml.)	55			4.5	45	136	8	2.4			55			4.5	9.						53	43	0.8	0.4	16.2
	136	37	12.2								212	295	11.4 (skimmed milk)								135	32	8.2		
																					165	132	54	13	187
IRON (mg./100 ml)	29		0.13								43			0.15	0.19	43		0.07			39	6	0.04		
	59a	7	0.10								59b		0.06			68		0.07			43	220	0.09	0.03	0.14
											164	14	0.36	0.29	0.45	118	31	0.02	0.01	0.05	44a,c	24	0.20	0.15	0.38
																					68			0.07	0.09
																					88		0.24		
																					103	61	0.03	0.01	0.06
																					121	20	0.04	0.03	0.05
																					132b	11	0.23		
																					164	25	0.36	0.14	1.00
																					174	6	0.05	0.05	0.06
																					198	4	0.05	0.04	0.07
LEAD (mg./100 ml.)											48	30	tr												
											107	52		0.001	0.018	49	4	tr			48	26	tr		
											210	4	0.016	0.005	0.032						49	12	tr		
LITHIUM (mg./100 ml.)											48	30	tr			49	4	tr			18		tr		
											49	6	tr								48	26	tr		
																					49	12	tr		
																					225		tr		
MANGANESE (mg./100 ml.)	29		tr								22		0.0007			109	4	0.008	0.007	0.009	6a	24	0.002		
											48	30	tr								22		0.001		
																					48	26	tr		
																					88		0.002		
																					109	6	0.003	0.003	0.004
																					132b	11	0.002		
MOLYBDENUM (mg./liter)											48	30	tr?			49	4	0			48	26	tr?		
											49	6	tr								49	12	tr		
NICKEL (mg./100 ml.)																					132b	11	0.013		
RUBIDIUM (mg./100 ml.)											48	30	tr								18		tr		
											183	2of5	1								48	26	tr		

	HUMAN COLOSTRUM, 1–5 days					TRANSITIONAL MILK, 6–10 days					MATURE HUMAN MILK					MATURE GOAT MILK					MATURE COW MILK				
	Ref. no.	No. detm.	Mean	Min.	Max.	Ref. no.	No. detm.	Mean	Min.	Max.	Ref. no.	No. detm.	Mean	Min.	Max.	Ref. no.	No. detm.	Mean	Min.	Max.	Ref. no.	No. detm.	Mean	Min.	Max.
Chemical Components—(*Continued*)																									
MINOR MINERAL CONSTITUENTS—(*Cont.*)																									
RUTHENIUM (*mg./100 ml.*)																					225		tr		
SILICON (*mg./100 ml.*)																					48	3	0		
																					225		tr		
SILVER (*mg./liter*)											49	6	tr			49	4	tr			49	12	tr		
STRONTIUM (*mg./100 ml.*)											48	30	tr			49	4	tr			18		tr		
											49	6	tr								48	26	tr		
																					49	12	tr		
																					225		tr		
TIN (*mg./100 ml.*)																					48	3	0		
TITANIUM (*mg./100 ml.*)											49	6	tr			49	4	tr			18		tr		
																					49	12	tr		
																					225		tr		
VANADIUM (*mg./100 ml.*)											49	6	tr			49	4	tr			49	12	tr		
																					225		tr		
ZINC (*mg./100 ml.*)	14	1	0.566			14	1	1.150			14	1	1.378			49	4	tr			14	28	0.42	0.20	0.56
	178a		0.74								22		0.35								22		0.34		
											48	30	tr								115			0.34	0.36
											49	6	tr								132b	11	0.281		
											115			0.14	0.21						178a			0.21	0.46
											178a	2	0.26	0.12	0.39										
MILK SALTS (*gm./100 ml.*)											20f		0.313			20f		0.939			20f		0.901		
DI-CALCIUM PHOSPHATE (*gm./100 ml.*)											20f		0.000			20f		0.092			20f		0.175		

TRI-CALCIUM PHOSPHATE (gm./100 ml.)											20f		0.000			20f		0.062			20f		0.000		
MONO-MAGNESIUM PHOSPHATE (gm./100 ml.)											20f		0.027			20f		0.000			20f		0.103		
DI-MAGNESIUM PHOSPHATE (gm./100 ml.)											20f		0.000			20f		0.068			20f		0.000		
TRI-MAGNESIUM PHOSPHATE (gm./100 ml.)											20f		0.000			20f		0.024			20f		0.000		
MONO-POTASSIUM PHOSPHATE (gm./100 ml.)											20f		0.069			20f		0.073			20f		0.000		
DI-POTASSIUM PHOSPHATE (gm./100 ml.)											20f		0.000			20f		0.000			20f		0.230		
POTASSIUM CITRATE (gm./100 ml.)											20f		0.103			20f		0.250			20f		0.052		
ODIUM CITRATE (gm./100 ml.)											20f		0.055			20f		0.000			20f		0.222		
POTASSIUM CHLORIDE (gm./100 ml.)											20f		0.000			20f		0.160			20f		0.000		
SODIUM CHLORIDE (gm./100. ml.)											20f		0.000			20f		0.095			20f		0.000		
CALCIUM CHLORIDE (gm./100 ml)											20f		0.059			20f		0.115			20f		0.119		
CARBOHYDRATE COMPONENTS																									
LACTOSE (gm./100 ml.)	12	88	6.4	4.6	7.4	12	88	6.7	4.8	7.6	12	81	7.1	6.0	8.3	20e	4	4.8	4.4	5.2	15	134	5.0		
	29		4.4			77	16	6.3	5.7	6.9	20f		6.5			52a		4.5			20f		4.9		
	59a	9	4.7			138	5	6.5	6.4	6.8	45	30	7.2			63	4	5.1	4.7	5.5	24	28	4.8	4.0	5.5
	77	16	5.8	2.3	6.9	221b,c	140	6.8	5.7	8.4	63	87	7.1			67	326	4.2			35	10	5.0	4.6	5.2
	108	3	4.7	3.6	6.6						69	1154	7.0			68		4.6			44c	150	4.8		
	221b,c	199	5.7	1.1	7.9						91	27	7.6	5.4	8.4	116	200	4.5	3.3	5.8	52a		4.8		
											108	10	7.5	7.0	7.8	152	18	5.1	4.3	6.0	63	21	4.5		
											132a	313	6.8	5.0	9.2	216	50	4.8	4.0	6.4	68			4.6	4.7
											144	184	6.0			213		4.8			116	800	4.9	2.1	6.1
											168	94	6.8	4.2	8.9						138	9	4.7	4.5	5.0
											221c	55	7.1	5.8	8.4						149	1998	4.9		
																					213		4.9		
																					219	208	4.5		

TABLE 1—(*Continued*)

	HUMAN COLOSTRUM, 1-5 days					TRANSITIONAL MILK, 6-10 days					MATURE HUMAN MILK					MATURE GOAT MILK					MATURE COW MILK				
	Ref. no.	No. detm.	Mean	Min.	Max.	Ref. no.	No. detm.	Mean	Min.	Max.	Ref. no.	No. detm.	Mean	Min.	Max.	Ref. no.	No. detm.	Mean	Min.	Max.	Ref. no.	No. detm.	Mean	Min.	Max.
Chemical Components—(*Continued*)																									
LIPID COMPONENTS																									
FAT (*gm./100 ml.*)	9		2.2			12	88	3.7	1.6	7.1	9		3.2			20e	4	3.2	2.2	3.8	20f		3.9		
	12	88	3.2	0.9	8.2	56	529	3.3 (first week)			12	81	3.8	1.1	7.6	40a	14	3.6	2.7	4.5	44c	247	3.2		
	29		2.8			66	10	3.0	1.5	4.5	20f		3.3			52a		3.8			46a	15	4.1	3.2	5.3
	59a	9	2.5			77	16	3.8	1.8	5.8	45	30	4.2			63	4	3.9	2.4	5.4	52a		3.8		
	66	7	2.3	1.2	3.8	132a	16	3.5	2.7	5.2	46a	37	3.9	0.7	8.0	67	326	4.1			68		4.4		
	77	16	3.6	1.9	12.7	148c	9	3.9	1.2	9.6	66	7	4.0	2.3	6.8	68		3.5			93	15	3.9	3.1	5.2
	84	25	2.7	0.7	3.8	221a	14	3.7	0.4	5.4	69	1154	3.8			90d	39	4.3	2.2	6.5	106	134	3.4	2.7	4.6
	132a	5	3.0	2.5	3.2						85a	7	4	3	5	116	200	4.8	3.1	7.6	116	800	3.6	1.7	6.5
	148c	4	4.1	1.5	7.6						91	27	3.2	1.0	6.2	152	18	4.8	2.3	6.5	132b	24	3.3		
	221a	7	2.6	1.4	3.4						97	45	3.4			211	40	3.9	3.7	5.1	137	130	4.0	0.9	7.1
											132a	408	4.5	1.3	8.3	213		4.2			138	9	4.3	3.2	5.4
											144	184	3.8			216	50	4.8	1.2	8.4	142		1.8		
											148c	5	5.2	2.7	8.4						146	102	3.8	1.6	6.2
											168	94	3.3	0.5	9.0						149	1998	4.4		
											203	1004	3.1								207	1449	4.4	1.9	9.8
											217	26	3.3	1.9	4.6						213		3.9		
																					219	208	3.6		
LIPOID PHOSPHORUS	85a	1	2			85a	5	3	2	4	26	9	2			85a	2	4	3	5	3	4	4	4	4
(*mg./100 ml. or /100 gm.*)											54		2								26	4	2		
											71	1	5								54		2		
											85a	11	3	2	4						71	3	3		
											113	1	3								72	18	6	4	14
											147	10		1	3						85a	9	6	5	7
											179		6								113	3	3	3	3
											196			7	7						147	17		1	5
																					179		4		
																					196			4	4

TOTAL CHOLESTEROL (*mg./100 ml. or /100 gm.*)	46a	1	13			66	10	29	14	44	46a	39	20	11	38	40a	15	24	17	39	5		12		
	66	7	31	24	45	142		26 (4–10 days)			66	7	27	13	47						34			12	15
	217	1	36								217	27	13	7	19						40c			12	13
																					46a	15	14	10	18
																					142		9		
																					145		13		
																							13		
																					146	109	11	7	17
																					185	9	22	17	28
																					208			10	12
FREE CHOLESTEROL (*mg./100 ml.*)																					146	7	12	10	15
LECITHIN (*mg./100 ml.*)											113	1	78								93	15	34	27	44
																					113	3	80	72	86
SOLUBLE ACIDS																	68		4.2	4.8	68			3.9	4.4
FATTY ACIDS (WEIGHT PERCENTAGE)																									
BUTYRIC ACID (WEIGHT PERCENTAGE)	9	2	0.2	0.2	0.2						9	1	0.4			47	1	3.0			4	1	3.5		
											23	2	tr	tr	tr	68	1	2.4			68	1	2.4		
																87b	1	3.0			87a,c	2	3.5	3.0	4.0
																169	1	2.1							
CAPROIC ACID (WEIGHT PERCENTAGE)	9	2	0.1	0.1	0.1						9	1	0.1			47	1	2.3			4	1	0.2		
																68	1	2.5			68	1	1.1		
																87b	1	2.5			87a,c	2	1.8	1.4	2.3
																169	1	1.9							
CAPRYLIC ACID (WEIGHT PERCENTAGE)	9	2	0.4	0.1	0.8						9	1	0.3			47	1	3.9			4	1	1.7		
											23	2	tr	tr	0.1	68	1	1.4			68	1	0.7		
																87b	1	2.8			87a,c	2	1.2	0.8	1.5
																169	1	2.7							
CAPRIC ACID (WEIGHT PERCENTAGE)	9	2	2.2	0.9	3.5	87d*	2	1.8	0.8	2.7	9	1	2.2			47	1	8.6			4	1	2.0		
											23	2	1.8	1.4	2.1	68	1	7.2			68	1	3.6		
											87d	2	1.1	0.5	1.7	87b	1	10.0			87a,c	2	2.3	1.9	2.7
																169	1	7.9							

---

* 1st 3 weeks.

TABLE 1—(*Continued*)

	HUMAN COLOSTRUM, 1-5 days					TRANSITIONAL MILK, 6-10 days					MATURE HUMAN MILK					MATURE GOAT MILK					MATURE COW MILK				
	Ref. no.	No. detm.	Mean	Min.	Max.	Ref. no.	No. detm.	Mean	Min.	Max.	Ref. no.	No. detm.	Mean	Min.	Max.	Ref. no.	No. detm.	Mean	Min.	Max.	Ref. no.	No. detm.	Mean	Min.	Max.
Chemical Components—(*Continued*)																									
FATTY ACIDS—(*Cont.*)																									
LAURIC ACID (WEIGHT PERCENTAGE)	9	2	1.8	0.9	2.6	87d*	2	5.6	5.1	6.1	9	1	5.5			47	1	4.6			4	1	1.4		
											23	2	5.1	4.8	5.4	68	1	3.9			68	1	2.3		
											87d	2	6.7	6.4	7.0	87b	1	6.0			87a,c	2	3.0	2.2	3.7
																169	1	3.5							
MYRISTIC ACID (WEIGHT PERCENTAGE)	9	2	3.8	2.8	4.9	87d*	2	9.4	8.1	10.8	9	1	8.5			47	1	11.5			4	1	8.3		
											23	2	6.6	6.6	6.7	68	1	10.4			68	1	12.6		
											87d	2	10.8	7.6	13.9	87b	1	12.3			87a,c	2	10.7	9.3	12.1
																169	1	10.2							
PALMITIC ACID (WEIGHT PERCENTAGE)	9	2	26.2	24.6	27.8	87d*	2	23.6	22.5	24.6	9	1	23.2			47	1	24.7			4	1	25.0		
											23	2	21.3	21.0	21.6	68	1	34.4			68	1	28.5		
											87d	2	23.2	22.4	24.1	87b	1	27.9			87a,c	2	25.4	25.3	25.5
																169	1	28.7							
STEARIC ACID (WEIGHT PERCENTAGE)	9	2	8.8	7.7	9.9	87d*	2	7.8	7.3	8.3	9	1	6.9			47	1	9.3			4	1	16.9		
											23	2	6.8	6.8	6.8	68	1	7.8			68	1	12.1		
											87d	2	9.3	9.0	9.6	87b	1	6.0			87a,c	2	10.5	9.2	11.8
																169	1	8.1							
FATTY ACIDS as ARACHIDIC ACID (WEIGHT PERCENTAGE)	9	2	3.8	2.7	4.9	87d*	2	1.4	1.0	1.8	9	1	1.1			47	1	0.1			4	1	1.5		
											87d	1	0.9			87b	1	0.6			87a,c	2	1.0	0.8	1.3
																169	1	0.4							
DECENOIC ACID (WEIGHT PERCENTAGE)	9	2	0.2	0.1	0.2	87d*	2	tr	tr	tr	9	1	0.1			68	1	0.2			4	1	0.3		
											23	2	tr	tr	tr	87b	1	0.3			68	1	0.2		
											87d	2	tr	tr	tr	169	1	0.2			87a,c	2	0.2	0.2	0.3
DODECENOIC ACID (WEIGHT PERCENTAGE)	9	2	0.1	0.1	0.1	87d*	2	0.1	0.1	0.1	9	1	0.1			87b	1	0.3			4	1	0.1		
											23	2	tr	tr	0.1						87a,c	2	0.3	0.2	0.4
											87d	2	0.1	0.1	0.1										

TETRADECENOIC ACID (WEIGHT PERCENTAGE)	9	2	0.2	0.1	0.2	87d*	2	0.8	0.4	1.3	9 23 87d	1 2 2	0.6 0.6 0.7	 0.4 0.5	 0.7 0.9	68 87b 169	1 1 1	0.4 0.8 0.4			4 68 87a,c	1 1 2	0.9 1.1 1.2	 0.9	 1.6
HEXADECENOIC ACID (WEIGHT PERCENTAGE)	9	2	2.4	1.8	2.9	87d*	2	3.2	3.1	3.3	9 23 87d	1 2 2	3.0 2.6 3.2	 2.6 2.8	 2.7 3.7	68 87b 169	1 1 1	2.7 2.6 2.1			4 68 87a,c	1 1 2	2.8 3.3 3.2	 2.3	 4.0
OLEIC ACID (WEIGHT PERCENTAGE)	9	2	36.6	36.0	37.1	87d*	2	34.6	32.8	36.4	9 23 87d	1 2 2	36.5 39.3 33.4	 39.1 30.2	 39.5 36.6	47 68 87b 169	1 1 1 1	30.5 25.2 21.1 31.2			4 68 87a,c	1 1 2	34.2 30.5 32.0	 29.6	 34.3
OCTADECADIENOIC ACID (WEIGHT PERCENTAGE)	9	2	6.8	6.2	7.5	87d*	2	7.1	6.3	7.9	9 23 87d	1 2 2	7.8 10.4 6.8	 10.3 5.5	 10.4 8.2	47 87b	1 1	1.5 3.6			87a,c	2	2.8	2.1	3.6
OCTADECATRIENOIC ACID (WEIGHT PERCENTAGE)	9	2	0.3	0.3	0.3						9 23	1 2	0.4 0.5	 0.5	 0.5										
as EICOSADIENOIC ACID (WEIGHT PERCENTAGE)	9	2	4.6	4.6	4.7						9	1	2.4												
EICOSATETRAENOIC ACID (WEIGHT PERCENTAGE)	9	2	1.7	1.6	1.8						9	1	0.9												
C 20–22 ACID (WEIGHT PERCENTAGE)	9	2	10.2	9.0	11.3	87d*	2	4.6	3.5	5.7	9 23 87d	1 2 2	4.4 4.0 4.2	 3.6 2.9	 4.3 5.4	87b 169	1 1	0.2 0.7			4 87a	1 1	0.7 1.4		
OCTADECATETRENOIC ACID (WEIGHT PERCENTAGE)											23	2	0.2	0.2	0.2										
ARACHIDONIC ACID (WEIGHT PERCENTAGE)											23	2	0.8	0.8	0.8	68	1	1.5			68 87c	1 1	1.6 0.3		
LINOLEIC ACID (WEIGHT PERCENTAGE)																					4	1	0.5		
BUTYRIC ACID (MOLAR PERCENTAGE)	9	2	0.8	0.7	0.8						9 23	1 2	1.1 tr	 tr	 tr	47 68 87b 169	1 1 1 1	7.6 5.7 7.5 5.2			4 68 87a,c	1 1 2	9.5 5.7 9.3	 8.1	 10.5

---

* 1st 3 weeks.

Copyrighted r

	HUMAN COLOSTRUM, 1–5 days					TRANSITIONAL MILK, 6–10 days					MATURE HUMAN MILK					MATURE GOAT MILK					MATURE COW MILK				
	Ref. no.	No. detm.	Mean	Min.	Max.	Ref. no.	No. detm.	Mean	Min.	Max.	Ref. no.	No. detm.	Mean	Min.	Max.	Ref. no.	No. detm.	Mean	Min.	Max.	Ref. no.	No. detm.	Mean	Min.	Max.
Chemical Components—(*Continued*)																									
FATTY ACIDS—(*Cont.*)																									
CAPROIC ACID (MOLAR PERCENTAGE)	9	2	0.2	0.2	0.3						9	1	0.1			47	1	4.5			4	1	0.4		
																68	1	4.5			68	1	2.0		
																87b	1	4.7			87a,c	2	3.7	2.8	4.6
																169	1	3.6							
CAPRYLIC ACID (MOLAR PERCENTAGE)	9	2	0.8	0.1	1.5						9	1	0.6			47	1	6.2			4	1	2.9		
											23	2	tr	tr	tr	68	1	2.0			68	1	1.0		
																87b	1	4.3			87a,c	2	1.9	1.3	2.5
																169	1	4.1							
CAPRIC ACID (MOLAR PERCENTAGE)	9	2	3.4	1.4	5.3	87d*	2	2.7	1.2	4.2	9	1	3.3			47	1	11.1			4	1	2.8		
											23	2	2.4	1.8	2.7	68	1	8.8			68	1	4.4		
											87d	2	1.6	0.8	2.5	87b	1	12.8			87a,c	2	3.2	2.7	3.7
																169	1	10.0							
LAURIC ACID (MOLAR PERCENTAGE)	9	2	2.3	1.2	3.4	87d*	2	7.4	6.7	8.0	9	1	7.1			47	1	5.1			4	1	1.7		
											23	2	5.7	5.4	6.1	68	1	4.1			68	1	2.4		
											87d	2	8.6	8.3	9.0	87b	1	6.6			87a,c	2	3.5	2.6	4.4
																169	1	3.8							
MYRISTIC ACID (MOLAR PERCENTAGE)	9	2	4.5	3.3	5.7	87d*	2	10.8	9.2	12.4	9	1	9.6			47	1	11.2			4	1	8.9		
											23	2	6.5	6.5	6.6	68	1	9.6			68	1	11.6		
											87d	2	12.2	8.7	15.8	87b	1	11.8			87a,c	2	11.0	9.6	12.5
																169	1	9.8							
PALMITIC ACID (MOLAR PERCENTAGE)	9	2	27.2	25.4	28.9	87d*	2	24.0	22.9	25.2	9	1	23.4			47	1	21.5			4	1	23.7		
											23	2	18.7	18.4	19.0	68	1	28.2			68	1	23.3		
											87d	2	23.6	22.8	24.4	87b	1	24.1			87a,c	2	23.3	23.2	23.4
																169	1	24.5							
STEARIC ACID (MOLAR PERCENTAGE)	9	2	8.2	7.2	9.2	87d*	2	7.2	6.7	7.7	9	1	6.3			47	1	7.3			4	1	14.4		
											23	2	5.4	5.4	5.4	68	1	5.8			68	1	8.9		
											87d	2	8.6	8.3	8.8	87b	1	4.7			87a,c	2	8.6	7.6	9.7
																169	1	6.2							

FATTY ACIDS as ARACHIDIC ACID (MOLAR PERCENTAGE)	9	2	3.2	2.3	4.1	87d*	2	1.2	0.8	1.5	9	1	0.9			47	1	0.1			4	1	1.1		
											87d	1	0.8			87b	1	0.4			87a,c	2	0.8	0.6	1.0
																169	1	0.3							
DECENOIC ACID (MOLAR PERCENTAGE)	9	2	0.2	0.1	0.3	87d*	2	tr	tr	tr	9	1	0.1			68	1	0.2			4	1	0.4		
											23	2	tr	tr	tr	87b	1	0.3			68	1	0.2		
											87d	2	tr	tr	tr	169	1	0.2			87a,c	2	0.3	0.2	0.4
DODECENOIC ACID (MOLAR PERCENTAGE)	9	2	0.1	0.1	0.1	87d*	2	0.1	0.1	0.1	9	1	0.1			87b	1	0.3			4	1	0.2		
											23	2	tr	tr	0.1						87a,c	2	0.6	0.2	0.9
											87d	2	0.2	0.1	0.2										
TETRADECENOIC ACID (MOLAR PERCENTAGE)	9	2	0.2	0.1	0.2	87d*	2	1.0	0.5	1.5	9	1	0.7			68	1	0.4			4	1	1.0		
											23	2	0.6	0.4	0.7	87b	1	0.8			68	1	1.0		
											87d	2	0.8	0.6	1.1	169	1	0.4			87a,c	2	1.4	1.0	1.7
HEXADECENOIC ACID (MOLAR PERCENTAGE)	9	2	2.4	1.9	3.0	87d*	2	3.2	3.1	3.4	9	1	3.0			68	1	2.2			4	1	2.7		
											23	2	2.3	2.3	2.4	87b	1	2.2			68	1	2.7		
											87d	2	3.4	2.9	3.8	169	1	1.8			87a,c	2	2.9	2.1	3.7
OLEIC ACID (MOLAR PERCENTAGE)	9	2	34.4	33.8	35.1	87d*	2	32.0	30.4	33.6	9	1	33.3			47	1	24.2			4	1	29.4		
											23	2	31.4	31.2	31.5	68	1	18.7			68	1	22.7		
											87d	2	30.8	27.6	33.9	87b	1	16.5			87a,c	2	26.7	24.8	28.6
																169	1	24.2							
OCTADECADIENOIC ACID (MOLAR PERCENTAGE)	9	2	6.5	5.9	7.1	87d*	2	6.6	5.9	7.3	9	1	7.2			47	1	1.2			87a,c	2	2.4	1.8	2.9
											23	2	7.5	7.5	7.5	87b	1	2.8							
											87d	2	6.4	5.1	7.7										
OCTADECATRIENOIC ACID (MOLAR PERCENTAGE)	9	2	0.2	0.2	0.3						9	1	0.4												
											23	2	0.3	0.3	0.3										
as EICOSADIENOIC ACID (MOLAR PERCENTAGE)	9	2	4.0	3.9	4.0						9	1	2.0												
EICOSATETRAENOIC ACID (MOLAR PERCENTAGE)	9	2	1.4	1.4	1.5						9	1	0.8												
C 20–22 ACID (MOLAR PERCENTAGE)	9	2	8.7	7.8	9.6	87d*	2	3.8	2.9	4.7	9	1	3.7			87b	1	0.2			4		0.5		
											23	2	2.8	2.5	3.0	169	1	0.5			87a	1	1.0		
											87d	2	3.4	2.4	4.4										
OCTADECATETRENOIC ACID (MOLAR PERCENTAGE)											23	2	0.1	0.1	0.1										

TABLE 1—(*Continued*)

	HUMAN COLOSTRUM, 1-5 days					TRANSITIONAL MILK, 6-10 days					MATURE HUMAN MILK					MATURE GOAT MILK					MATURE COW MILK				
	Ref. no.	No. detm.	Mean	Min.	Max.	Ref. no.	No. detm.	Mean	Min.	Max.	Ref. no.	No. detm.	Mean	Min.	Max.	Ref. no.	No. detm.	Mean	Min.	Max.	Ref. no.	No. detm.	Mean	Min.	Max.
Chemical Components—(*Continued*)																									
FATTY ACIDS—(*Cont.*)																									
ARACHIDONIC ACID (MOLAR PERCENTAGE)											23	2	0.6	0.6	0.6	68	1	1.0			68 88c	1 1	1.1 0.2		
LINOLEIC ACID (MOLAR PERCENTAGE)																					4		0.4		
PHOSPHORUS DISTRIBUTION																									
PHOSPHORUS, Acid-Soluble, Total (mg./100 ml.)																19	14	86			3 72	15 18	86.9 77.7	74.5 64.5	98.3 97.0
PHOSPHORUS, Acid-Soluble, Inorganic (mg./100 ml.)																					72	18	67.6	54.6	88.0
PHOSPHORUS, Acid-Soluble, Ester (mg./100 ml.)																					72*	18	10.2	7.0	20.1
PHOSPHORUS, Acid-Insoluble Total (mg./100 ml.)																					3 72	8 18	26.1 25.8	22.0 17.7	31.3 34.8
RIBONUCLEIC ACID PHOSPHORUS (mg./100 ml.)											134			0.2	0.3	134			2.0	2.6	134			1.5	1.7
TOTAL INORGANIC PHOSPHORUS (mg./100 ml.)											13 25	2 51	5.5 5.13	3.6 1.5	7.4 8.77	152 20e	11 4	77.2 81.0	57.7 72.0	94.5 105.3	13 214b	3	72.4 87	69.4	74.5
TOTAL ORGANIC PHOSPHORUS (mg./100 ml.)																20e	4	14.4	12.0	15.9					

NITROGENOUS COMPONENTS																									
PROTEIN (gm./100 ml.)	12	88	2.0	1.4	2.8	12	88	1.7	1.1	2.6	12	81	1.3	1.0	1.8	20e	4	2.9	2.5	3.2	35	10	3.7	3.3	4.1
	29		2.2			77	16	1.6	1.4	1.9	45	30	1.2			52a		3.2			44b	62	2.9	2.4	3.7
	59a	9	2.1			132a	44	1.6	1.3	1.9	59c	27	0.9	0.8	1.0	63	4	2.9	2.1	3.7	52a		3.5		
	77	16	2.6	1.3	5.8	138	5	1.6	1.2	1.8	63	87	1.4			67	326	3.7			59c		2.9		
	91	2	2.0	2.0	2.1	218*	160	1.6	1.1	2.7	69	1154	1.6			68		3.1			68			3.2	3.8
	132a	33	2.3	1.5	6.8	221b	56	1.6	0.8	2.0	91	27	1.1	0.8	1.5	90c	27	3.4	2.7	4.0	106	134	3.1	2.5	5.0
	218	167	5.5	1.4	21.5						97	43	1.3			116	200	4.3			116	800	3.6	2.1	6.4
	221b	100	3.2	1.2	14.1						132a	583	1.1	0.7	2.0	152	18	3.5	2.5	4.5	132b	24	3.0	2.8	3.3
											138	2	1.1	1.0	1.2	213		3.3			138	9	3.4	3.1	3.7
											144	184	1.6			216	50	3.6	2.1	4.8	149	1998	3.8		
											153	31	1.0	0.8	1.3						153	6	3.0	3.0	3.0
											168	94	1.5	0.8	5.6						173	16	3.3	2.9	4.1
											221c	56	1.1	0.8	1.4						213		3.5		
																					219	208	3.1		
CASEIN PROTEIN (gm./100 ml.)	91	1	0.3			132a	2	0.5	0.4	0.6	10	4	0.310			20e	4	2.032	1.701	2.249	3	10	3.9		
	218	40	2.058	0.726	5.172	218*	84	0.917	0.408	1.841	37		0.382			68		2.236			5		2.8		
											68		0.461			116	200	3.2	2.4	3.9	10	3	2.580		
											91	24	0.40	0.04	0.64						35	10	2.9	2.5	3.3
											132a	166	0.37	0.14	0.68						44b	62	2.2	1.4	3.1
											153	31	0.32	0.14	0.59						68	41		2.344	3.115
																					116	800	3.0	1.8	6.3
																					153	6	2.3	2.1	2.4
																					173	16	2.745	2.357	3.370
																					214b		3.1		
WHEY PROTEIN (gm./100 ml.)	91	1	1.7								10	4	0.490			116	200	1.1	0.8	2.0	10	3	0.567		
											37		0.334								44b	62	0.67	0.36	0.94
											91	24	0.7	0.5	1.1						116	800	0.5	0.2	1.4
											153	31	0.7	0.4	1.0						153	6	0.7	0.6	0.9
																					173	16	0.440	0.331	0.599
LACTALBUMIN PROTEIN (gm./100 ml.)						132a	2	0.8	0.7	0.8	68		0.299			20e	4	0.440	0.376	0.573	44b	58	0.42	0.27	0.57
											132a	163	0.36	0.14	0.60	68		0.417			68			0.287	0.369
																					173	9	0.303	0.231	0.387
																					214b		0.5		
LACTOGLOBULIN PROTEIN (gm./100 ml.)	218	39	3.542	0.420	13.250	218*	83	0.497	0.210	1.363	68		0.172			68		0.261			44b	58	0.26	0.14	0.42
																					68			0.210	0.274
																					173	9	0.110	0.085	0.135

---

* 5–14 days.

	HUMAN COLOSTRUM, 1–5 days					TRANSITIONAL MILK, 6–10 days					MATURE HUMAN MILK					MATURE GOAT MILK					MATURE COW MILK				
	Ref. no.	No. detm.	Mean	Min.	Max.	Ref. no	No. detm.	Mean	Min.	Max.	Ref. no.	No. demt.	Mean	Min.	Max.	Ref. no.	No. detm.	Mean	Min.	Max.	Ref. no.	No. detm.	Mean	Min.	Max.
Chemical Components—*(Continued)*																									
NON-PROTEIN NITROGEN DISTRIBUTION																									
NON-PROTEIN NITROGEN	218	7	91	51	127	132a	2	48	42	53	10	4	36			68		40			44b	62	42	20	67
(mg./100 ml.)						218*	21	84	48	140	37		62								46b	3	23	21	26
											46b	3	33	26	37						59c		30		
											59c	40	32								68			27	30
											68		29								153	6	42	33	50
											132a	151	32	17	60						173	16	28	21	33
											153	31	47	37	68										
NON-PROTEIN CREATINE											46b	3	3.5	3.2	3.9						46b	3	2.4	2.3	2.4
(mg./100 ml.)											132a	41	3.1	0	12.4										
NON-PROTEIN CREATININE											46b	3	1.5	1.1	1.8						3	6	0.6	0.5	0.7
(mg./100 ml.)											132a	44	3.0	2.0	5.1						46b	3	1.4	1.4	1.5
NON-PROTEIN UREA						132a	1	23.3			46b	3	26.5	25.2	29.0						46b	3	19.5	18.9	21.0
(mg./100 ml.)											132a	52	37.8	26.7	49.4										
NON-PROTEIN URIC ACID											46b	3	2.5	2.2	2.7						46b	3	1.5	1.4	1.6
(mg./100 ml.)											132a	56	6.6	3.9	12.3										
NON-PROTEIN AMINO ACID, NITROGEN						132a	2	4	4	5	46b	3	7.2	4.6	8.6						46b	3	4.2	4.0	4.3
(mg./100 ml.)											132a	157	5.0	2.8	11.3										
AMINO ACIDS																									
TOTAL ALANINE											223		35								223		75		
(mg./100 ml.)																									
TOTAL ARGININE	132a	13	74	62	96	17		107 (2–9 days)			10		40								10		127		
(mg./100 ml.)						132a	24	63	48	73	17		56								17		140		
											132a	25	43	28	64						89c	6	100	90	120
											153		46								153		113		
											223		67								195		122		
																					223		127		

TOTAL ASPARTIC ACID (mg./100 ml.)											223		116								223		166		
TOTAL CYSTINE (mg./100 ml.)						17		48 (2–9 days)			10		20								10		23		
											17		22								17		28		
											153		32								153		32		
											223		41								223		27		
TOTAL GLUTAMIC ACID (mg./100 ml.)											223		230								223		680		
TOTAL GLYCINE (mg./100 ml.)											223		0								223		11		
TOTAL HISTIDINE (mg./100 ml.)	132a	13	41	33	46	17		50 (2–9 days)			10		12								10		59		
						132a	24	38	29	45	17		38								17		104		
											132a	25	24	12	30						89c	6	70	60	80
											153		16								153		51		
											223		25								195		82		
																					223		63		
TOTAL ISOLEUCINE (mg./100 ml.)	132a	13	101	88	115	17		105 (2–9 days)			17		105								17		340		
						132a	24	97	73	121	132a	25	61	41	92						89c	6	200	170	230
											223		75								195		177		
																					223		167		
TOTAL LEUCINE (mg./100 ml.)	132a	13	166	133	214	17		153 (2–9 days)			17		137								17		424		
						132a	24	151	113	197	132a	25	97	65	147						89c	6	340	310	360
											223		228								195		337		
																					223		490		
TOTAL LYSINE (mg./100 ml.)	132a	12	118	95	141	17		124 (2–9 days)			10		50								10		223		
						132a	24	113	88	148	17		98								17		276		
											132a	25	70	36	93						89c		280	240	340
											153		62								153		184		
											223		94								195		296		
																					223		200		
TOTAL METHIONINE (mg./100 ml.)	132a	13	25	19	36	17		35 (2–9 days)			10		18								10		104		
						132a	24	24	16	34	17		31								17		144		
											132a	24	12	6	16						89c	6	60	50	80
											153		18								153		82		
											223		29								195		71		
																					223		99		

---

* 5–14 days.

TABLE 1—(*Continued*)

	HUMAN COLOSTRUM, 1–5 days					TRANSITIONAL MILK, 6–10 days					MATURE HUMAN MILK					MATURE GOAT MILK					MATURE COW MILK				
	Ref. no.	No. detm.	Mean	Min.	Max.	Ref. no.	No. detm.	Mean	Min.	Max.	Ref. no.	No. detm.	Mean	Min.	Max.	Ref. no.	No. detm.	Mean	Min.	Max.	Ref. no.	No. detm.	Mean	Min.	Ma
Chemical Components—(*Continued*)																									
AMINO ACIDS—(*Cont.*)																									
TOTAL PHENYLALANINE	132a	13	70	60	84	17		114 (2–9 days)			17		74								17		228		
(*mg./100 ml.*)						132a	24	62	48	71	132a	25	40	24	58						89c	6	140	120	150
											223		77								195		180		
																					223		177		
TOTAL PROLINE											223		80								223		250		
(*mg./100 ml.*)																									
TOTAL SERINE (*mg./100 ml.*)											223		69								223		160		
TOTAL THREONINE	132a	13	85	75	104	17		97 (2–9 days)			17		63								17		180		
(*mg./100 ml.*)						132a	24	78	61	91	132a	25	52	30	66						89c	6	140	130	150
											223		63								195		136		
																					223		151		
TOTAL TYROSINE						17		105 (2–9 days)			10		50								10		197		
(*mg./100 ml.*)											17		73								17		256		
											153		47								89c	6	170	160	180
											223		73								153		158		
																					223		172		
TOTAL TRYPTOPHANE	132a	12	32	25	42	17		39 (2–9 days)			10		19								10		43		
(*mg./100 ml.*)						132a	23	28	23	32	17		22								17		56		
											132a	24	19	14	26						89c	6	43	40	49
											153		20								153		44		
											223		31								195		45		
																					223		47		
TOTAL VALINE (*mg./100 ml.*)	132a	13	117	98	149	17		134 (2–9 days)			17		123								17		336		
						132a	24	105	77	136	132a	25	72	45	114						89c	6	200	190	220
											223		66								195		224		
																					223		171		

CASEIN ALANINE (gm./100 gm. Casein)											223		2.0			162	1	1.8			223		2.3		
CASEIN ARGININE (gm./100 gm. Casein)											10		3.31			123	2	1.32	1.29	1.36	10		3.79		
											153	31	3.58			162	2	4.0	4.0	4.1	82	5	3.78		
											223		3.4								86		3.6		
																					131	2	3.71	3.61	3.81
																					153	6	3.73		
																					195		3.9		
																					215a	11	3.72		
																					223		3.9		
CASEIN ASPARTIC ACID (gm./100 gm. Casein)											223		4.6			162	1	1.7			82	2	7.4		
																					223		4.2		
CASEIN CYSTINE (gm./100 gm. Casein)											10		0.73			123	2	tr	0.00	tr	10		0.26		
											153	31	0.60								153	6	0.36		
											223		0.6								223		0.4		
CASEIN GLUTAMIC ACID (gm./100 gm. Casein)											223		20.9			162	1	12.1			82	6	21.7		
																					86		21.4		
																					223		21.9		
CASEIN GLYCINE (gm./100 gm. Casein)											223		0								223		0.4		
CASEIN HISTIDINE (gm./100 gm. Casein)											10		1.80			123	2	3.30	3.30	3.31	10		1.81		
											153	31	1.52			162	2	0.4	0.4	0.5	82	4	3.03		
											223		2.0								86		2.6		
																					153	6	1.67		
																					195		2.8		
																					215b	2	1.83	1.79	1.86
																					223		2.0		
CASEIN ISOLEUCINE (gm./100 gm. Casein)											223		6.3								82	9	7.6		
																					86		6.0		
																					196		5.6		
																					223		5.2		
CASEIN LEUCINE (gm./100 gm. Casein)											223		12.2			162	1	11.4			82	8	10.25		
																					86		9.5		
																					175		9.8		
																					195		9.9		
																					223		14.4		

TABLE 1—(*Continued*)

	HUMAN COLOSTRUM, 1–5 days					TRANSITIONAL MILK, 6–10 days					MATURE HUMAN MILK					MATURE GOAT MILK					MATURE COW MILK				
	Ref. no.	No. detm.	Mean	Min.	Max.	Ref. no.	No. detm.	Mean	Min.	Max.	Ref. no.	No. detm.	Mean	Min.	Max.	Ref. no.	No. detm.	Mean	Min.	Max.	Ref. no.	No. detm.	Mean	Min.	Max.
Chemical Components—(*Continued*)																									
AMINO ACIDS—(*Cont.*)																									
CASEIN LYSINE (*gm./100 gm. Casein*)											10		5.21			162	2	3.7	3.5	3.9	10		6.20		
											153	31	5.46								82	3	8.07		
											223		5.6								86		7.6		
																					153	6	6.13		
																					195	3	7.7	7.6	7.8
																					215b	2	6.25	6.24	6.26
																					223		6.0		
CASEIN METHIONINE (*gm./100 gm. Casein*)											10		2.19								10		3.10		
											153	31	2.70								82	8	2.69		
											223		2.3								153	6	2.89		
																					195		2.6		
																					223		3.1		
CASEIN PHENYLALANINE (*gm./100 gm. Casein*)											223		5.8			162	1	2.0			82	8	5.45		
																					86		5.3		
																					195		5.9		
																					223		5.5		
CASEIN PROLINE (*gm./100 gm. Casein*)											223		8.9			162	1	6.9			82	6	11.6		
																					223		8.1		
CASEIN SERINE (*gm./100 gm. Casein*)											223		5.4			162	1	0.7			163		5.90		
																					223		5.0		
CASEIN THREONINE (*gm./100 gm. Casein*)											223		4.5								82	10	4.28		
																					86		4.1		
																					163		4.55		
																					195		4.2		
																					223		4.6		

CASEIN TRYPTOPHANE (gm./100 gm. Casein)											10		1.69			123	2	1.04	1.00	1.07	10		1.11		
											153	31	1.05			162	1	1.7			82	1	1.28		
											223		1.5								153	6	1.36		
																					175		1.20		
																					195		1.07		
																					223		1.3		
CASEIN TYROSINE (gm./100 gm. Casein)											10		6.11			123	2	4.84	4.78	4.89	10		6.01		
											153	31	5.45			162	1	4.9			73		5.6		
											223		5.5								82	6	6.2		
																					86		6.5		
																					153	6	5.80		
																					175		6.10		
																					223		5.5		
CASEIN VALINE (gm./100 gm. Casein)											223		5.0			162	1	6.0			82	11	7.15		
																					86		7.1		
																					92		6.9		
																					131	6	6.7		
																					195		6.7		
																					223		5.3		
WHEY ARGININE (gm./100 gm. Whey)											10		5.18								10		3.46		
											153	31	5.03								153	6	4.01		
WHEY CYSTINE (gm./100 gm. Whey)											10		3.09								10		2.49		
											153	31	4.14								153	6	3.31		
WHEY HISTIDINE (gm./100 gm. Whey)											10		1.13								10		1.41		
											153	31	1.66								153	6	1.82		
WHEY LYSINE (gm./100 gm. Whey)											10		5.80								10		7.91		
											153	31	6.57								153	6	6.27		
WHEY METHIONINE (gm./100 gm. Whey)											10		1.91								10		2.73		
											153	31	1.40								153	6	2.29		
WHEY TRYPTOPHANE (gm./100 gm. Whey)											10		2.32								10		1.81		
											153	31	2.47								153	6	1.90		
WHEY TYROSINE (gm./100 gm. Whey)											10		5.20								10		4.70		
											153	31	4.48								153	6	3.64		

TABLE 1—(*Continued*)

	HUMAN COLOSTRUM, 1–5 days					TRANSITIONAL MILK, 6–10 days					MATURE HUMAN MILK					MATURE GOAT MILK					MATURE COW MILK				
	Ref. no.	No. detm.	Mean	Min.	Max.	Ref. no.	No. detm.	Mean	Min.	Max.	Ref. no.	No. detm.	Mean	Min.	Max.	Ref. no.	No. detm.	Mean	Min.	Max.	Ref. no.	No. detm.	Mean	Min.	Max.
Chemical Components—(*Continued*)																									
AMINO ACIDS—(*Cont.*)																									
LACTALBUMIN ALANINE (*gm./100 gm. Lactalbumin*)											223		2.5								223		2.6		
LACTALBUMIN ARGININE (*gm./100 gm. Lactalbumin*)											223		5.0			123	2	2.08	2.07	2.08	86 223	3	3.2 3.6	3.1	3.3
LACTALBUMIN ASPARTIC ACID (*gm./100 gm. Lactalbumin*)											223		9.3								223		9.6		
LACTALBUMIN CYSTINE (*gm./100 gm. Lactalbumin*)											223		3.8			123	2	3.72	3.60	3.85	223		3.1		
LACTALBUMIN GLUTAMIC ACID (*gm./100 gm. Lactalbumin*)											223		12.5								86 223	3	16.8 13.7	16.2	17.2
LACTALBUMIN GLYCINE (*gm./100 gm. Lactalbumin*)											223		0								223		0		
LACTALBUMIN HISTIDINE (*gm./100 gm. Lactalbumin*)											223		1.5			123	2	2.64	2.59	2.70	86 223	3	1.8 1.4	1.7	1.9
LACTALBUMIN ISOLEUCINE (*gm./100 gm. Lactalbumin*)											223		4.3								86 223	3	6.0 4.2	5.8	6.3
LACTALBUMIN LEUCINE (*gm./100 gm. Lactalbumin*)											223		16.7								86 223	3	10.8 17.4	10.6	11.1
LACTALBUMIN LYSINE (*gm./100 gm. Lactalbumin*)											223		6.6								86 223	3	8.4 6.2	8.3	8.5

LACTALBUMIN METHIONINE (gm./100 gm. Lactalbumin)											223		1.7								223		2.4		
LACTALBUMIN PHENYLALANINE (gm./100 gm. Lactalbumin)											223		4.8								86 223	3	3.7 4.5	3.5	3.9
LACTALBUMIN PROLINE (gm./100 gm. Lactalbumin)											223		3.5								223		4.0		
LACTALBUMIN SERINE (gm./100 gm. Lactalbumin)											223		4.2								223		4.0		
LACTALBUMIN THREONINE (gm./100 gm. Lactalbumin)											223		4.0								86 223	3	5.6 4.3	5.1	6.1
LACTALBUMIN TRYPTOPHANE (gm./100 gm. Lactalbumin)											223		2.3			123	2	2.44	2.27	2.62	223		2.1		
LACTALBUMIN TYROSINE (gm./100 gm. Lactalbumin)											223		4.5			123	2	4.17	4.06	4.28	86 223	3	4.6 3.5	4.2	4.9
LACTALBUMIN VALINE (gm./100 gm. Lactalbumin)											223		4.1								86 223	3	5.9 4.0	5.6	6.2
LACTALBUMIN NITROGEN (gm./100 gm. Lactalbumin)											223		14.94								223		14.92		
LACTOGLOBULIN ALANINE (gm./100 gm. Lactoglobulin)																					21 111 193b	 2 1	6.2 7.06 7.09	7.00	7.11
LACTOGLOBULIN AMIDE NH_3 (gm./100 gm. Lactoglobulin)																					21		1.31		
LACTOGLOBULIN ARGININE (gm./100 gm. Lactoglobulin)																123*	2	1.70	1.69	1.70	21 32 131* 193b	 2 2 1	2.88 2.89 2.91 2.91	2.90	2.92

* Values given as "Lactoglobulin" are marked with an asterisk (*); all other values were designated as "beta-Lactoglobulin."

TABLE 1—(*Continued*)

	HUMAN COLOSTRUM, 1–5 days					TRANSITIONAL MILK, 6–10 days					MATURE HUMAN MILK					MATURE GOAT MILK					MATURE COW MILK				
	Ref. no.	No. detm.	Mean	Min.	Max.	Ref. no.	No. detm.	Mean	Min.	Max.	Ref. no.	No. detm.	Mean	Min.	Max.	Ref. no.	No. detm.	Mean	Min.	Max.	Ref. no.	No. detm.	Mean	Min.	Max.
Chemical Components—(*Continued*)																									
AMINO ACIDS—(*Cont.*)																									
LACTOGLOBULIN ASPARTIC ACID (*gm./100 gm. Lactoglobulin*)																					21		11.4		
																					32	2	9.88		
																					65	2	11.2	11.2	11.3
																					193b	1	11.52		
LACTOGLOBULIN CYSTINE (*gm./100 gm. Lactoglobulin*)																123*	2	1.78	1.68	1.88	150*		4.0		
LACTOGLOBULIN CYSTEINE (*gm./100 gm. Lactoglobulin*)																					21		1.11		
LACTOGLOBULIN HALF-CYSTINE (*gm./100 gm. Lactoglobulin*)																					21		2.29		
LACTOGLOBULIN GLUTAMIC ACID, TOTAL (*gm./100 gm. Lactoglobulin*)																					21		19.5		
																					32	2	21.51		
																					65	2	19.0	19.0	19.1
																					193b	1	19.08		
LACTOGLOBULIN GLUTAMIC ACID, FREE (*gm./100 gm. Lactoglobulin*)																					21		8.2		
LACTOGLOBULIN GLUTAMINE (*gm./100 gm. Lactoglobulin*)																					21		11.2		

Copyright material

LACTOGLOBULIN GLYCINE (gm./100 gm. *Lactoglobulin*)																					21		1.4		
																					65	2	1.5	1.5	1.5
																					111	2	1.56	1.54	1.58
																					193b	1	1.39		
LACTOGLOBULIN HISTIDINE (gm./100 gm. *Lactoglobulin*)																123*	2	2.27	2.24	2.30	21		1.58		
																					32	2	1.54		
																					193b	1	1.63		
LACTOGLOBULIN ISOLEUCINE (gm./100 gm. *Lactoglobulin*)																					21		8.4		
																					188b		6.1		
																					193a	3	5.86	5.74	6.04
LACTOGLOBULIN LEUCINE (gm./100 gm. *Lactoglobulin*)																					21		15.6		
																					65	2	15.6	15.6	15.7
																					175		15.4		
																					193a	3	15.5	15.4	15.7
LACTOGLOBULIN LYSINE (gm./100 gm. *Lactoglobulin*)																					21		11.4		
																					32	2	9.75		
																					65	2	11.4	11.4	11.4
																					193b	1	12.58		
LACTOGLOBULIN METHIONINE (gm./100 gm. *Lactoglobulin*)																					21		3.22		
LACTOGLOBULIN PHENYLALANINE (gm./100 gm. *Lactoglobulin*)																					21		3.54		
																					193a	3	3.78	3.74	3.82
LACTOGLOBULIN PROLINE (gm./100 gm. *Lactoglobulin*)																					21		4.1		
																					111	2	4.84	4.79	4.89
																					193b	1	5.14		
LACTOGLOBULIN SERINE (gm./100 gm. *Lactoglobulin*)																					21		5.0		
																					163		4.07		
																					193b	1	3.96		

---

* Values given as "Lactoglobulin" are marked with an asterisk (*); all other values were designated as "beta-Lactoglobulin.'

TABLE 1—(*Continued*)

	HUMAN COLOSTRUM, 1–5 days					TRANSITIONAL MILK, 6–10 days					MATURE HUMAN MILK					MATURE GOAT MILK					MATURE COW MILK				
	Ref. no.	No. detm.	Mean	Min.	Max.	Ref. no.	No. detm.	Mean	Min.	Max.	Ref. no.	No. detm.	Mean	Min.	Max.	Ref. no.	No. detm.	Mean	Min.	Max.	Ref. no.	No. detm.	Mean	Min.	Max.
Chemical Components—(*Continued*)																									
AMINO ACIDS—(*Cont.*)																									
LACTOGLOBULIN THREONINE (*gm./100 gm. Lactoglobulin*)																					21		5.85		
																					163		5.11		
																					193b	1	4.92		
LACTOGLOBULIN TRYPTOPHANE (*gm./100 gm. Lactoglobulin*)																123*	2	1.84	1.80	1.87	21		1.94		
																					175		1.94		
LACTOGLOBULIN TYROSINE (*gm./100 gm. Lactoglobulin*)																123*	2	3.99	3.98	4.00	21		3.78		
																					73		3.6		
																					175		3.72		
																					193a	3	3.64	3.52	3.81
LACTOGLOBULIN VALINE (*gm./100 gm. Lactoglobulin*)																					21		5.83		
																					193a	3	5.62	5.55	5.71
																					131*	2	5.80	5.56	6.05
CASEIN COMPONENTS																									
ASH (*gm./100 gm. Casein*)																20d		0.36			214a		0.06		
CARBON (*gm./100 gm. Casein*)											124			51.56	53.6	20d		52.50			20a		53.50		
											133		52.35								27		52.83		
											139	8	53.37	52.47	53.78						33		53.30		
											226		52.24								76		52.96		
																					127		54		
																					139	4	53.40	53.05	53.90
																					158		52.88		
																					205		52.69		

HYDROGEN (*gm./100 gm. Casein*)											124			6.77	7.22	20d		7.16			20a		7.13		
											133		7.27								27		7.10		
											139	8	7.05	6.83	7.20						33		7.07		
											226		7.32								76		7.05		
																					127		7.04		
																					139	4	7.01	6.91	7.13
																					158		7.00		
																					205		6.76		
NITROGEN (*gm./100 gm. Casein*)											10		14.62			20d		15.67			10		14.50		
											20c		15.75								16		15.52		
											124			14.04	15.0						27		15.64		
											133		14.65								33		15.91		
											139	9	14.99	14.52	15.18						76		15.65		
											153	31	14.37								92		16.07		
											223		14.90								127		15.6		
											226		14.97								139	5	15.54	15.05	16.08
																					153	6	15.24		
																					158		15.51		
																					177		15.54		
																					205		15.65		
																					214a		15.80		
																					215c	8	15.75		
																					223		15.28		
OXYGEN (*gm./100 gm. Casein*)											139	7	22.56	22.01	22.98	20d		23.25			20a		22.08		
											226		23.66								27		22.91		
																					33		22.03		
																					76		22.78		
																					127		21.74		
																					139	4	22.72	22.16	23.24
																					158		23.05		
																					205		23.14		
PHOSPHORUS (*gm./100 gm. Casein*)											20c		0.70			20d		0.71			16		0.83		
											124			0.22	0.29						27		0.81		
											139	10	0.44	0.32	0.51						33		0.87		
											153	31	0.45								76		0.85		
											226		0.68								127		0.85		
																					139	5	0.80	0.76	0.85
																					153	6	0.84		
																					158		0.79		
																					177		0.84		
																					205		0.88		
																					214a		0.71		

---

* Values given as "Lactoglobulin" are marked with an asterisk (*); all other values were designated as "beta-Lactoglobulin."

Copyri

TABLE 1—(*Continued*)

	HUMAN COLOSTRUM, 1–5 days					TRANSITIONAL MILK, 6–10 days					MATURE HUMAN MILK					MATURE GOAT MILK					MATURE COW MILK				
	Ref. no.	No. detm.	Mean	Min.	Max.	Ref. no.	No. detm.	Mean	Min.	Max.	Ref. no.	No. detm.	Mean	Min.	Max.	Ref. no.	No. detm.	Mean	Min.	Max.	Ref. no.	No. detm.	Mean	Min.	Max.
Chemical Components—(*Continued*)																									
CASEIN COMPONENTS—(*Cont.*)																									
SULFUR (*gm./100 gm. Casein*)											10		0.682			20d		0.71			10		0.796		
											20c		0.70								16		0.75		
											124			0.33	0.85						20a		0.72		
											127		1.09								27		0.73		
											139	6	0.93	0.65	1.25						33		0.82		
											153	31	0.78								76		0.72		
											226		1.12								127		0.77		
																					139	4	0.76	0.64	0.88
																					153	6	0.65		
																					158		0.77		
																					205		0.83		
CASEIN CYSTINE SULFUR (*gm./100 gm. Casein*)											10		0.195								10		0.069		
CASEIN METHIONINE SULFUR (*gm./100 gm. Casein*)											10		0.471								10		0.666		
CASEIN CYSTINE SULFUR + METHIONINE SULFUR (*gm./100 gm. Casein*)											10		0.666								10		0.735		
BETA-LACTOGLOBULIN COMPONENTS																									
CARBON (*gm./100 gm. beta-Lactoglobulin*)																					21		53.39		
HYDROGEN (*gm./100 gm. beta-Lactoglobulin*)																					21		7.22		

TOTAL NITROGEN (gm./100 gm. beta-Lactoglobulin)																				21		15.60		
TOTAL SULFUR (gm./100 gm. beta-Lactoglobulin)																				21		1.60		
OXYGEN (gm./100 gm. beta-Lactoglobulin)																				21		22.19		
CYSTEINE SULFUR + CYSTINE SULFUR (gm./100 gm. beta Lactoglobulin)																				21		0.905		
METHIONINE SULFUR (gm./100 gm. beta-Lactoglobulin)																				21		0.692		
SULFATE SULFUR (gm./100 gm. beta-Lactoglobulin)																				21		0.0		
AMIDE NITROGEN (gm./100 gm. beta-Lactoglobulin)																				21		1.076		
INDOLE NITROGEN (gm./100 gm. beta-Lactoglobulin)																				21		0.133		
GUANIDINO NITROGEN (gm./100 gm. beta-Lactoglobulin)																				21		0.695		
IMIDAZOLE NITROGEN (gm./100 gm. beta-Lactoglobulin)																				21		0.285		
ε-AMINO NITROGEN (gm./100 gm. beta-Lactoglobulin)																				21		1.092		
NON alpha-NITROGEN (gm./100 gm. beta-Lactoglobulin)																				21		3.28		

TABLE 1—*(Continued)*

	HUMAN COLOSTRUM, 1–5 days					TRANSITIONAL MILK, 6–10 days					MATURE HUMAN MILK					MATURE GOAT MILK					MATURE COW MILK				
	Ref. no.	No. detm.	Mean	Min.	Max.	Ref. no.	No. detm.	Mean	Min.	Max.	Ref. no.	No. detm.	Mean	Min.	Max.	Ref. no.	No. detm.	Mean	Min.	Max.	Ref. no.	No. detm.	Mean	Min.	Max.
Chemical Components—*(Continued)*																									
BETA-LACTOGLOBULIN COMPONENTS—*(Cont.)*																									
alpha-NITROGEN (gm./100 gm. beta-Lactoglobulin)																					21		12.319		
FREE AMINO NITROGEN (gm./100 gm. beta-Lactoglobulin)																					21		1.247		
FREE alpha-AMINO NITROGEN (gm./100 gm. beta-Lactoglobulin)																					21		0.155		
PEPTIDE NITROGEN (gm./100 gm. beta-Lactoglobulin)																					21		12.164		
WHEY COMPONENTS																									
PROTEIN SULFUR (gm./100 gm. Whey)											10 153	31	1.298 1.65								10 153	6	1.262 1.52		
CYSTINE SULFUR (gm./100 gm. Whey)											10		0.825								10		0.662		
METHIONINE SULFUR (gm./100 gm. Whey)											10		0.410								10		0.586		
CYSTINE SULFUR + METHIONINE SULFUR (gm./100 gm. Whey)											10		1.235								10		1.248		

VITAMINS, Fat-soluble																									
VITAMIN A (*mmg./100 ml.*)	59a	9	54			132a	26	88	58	183	97	45	48								59b		66		
	84	21	51	16	125						132a	264	61	15	226						74b		12		
	132a	24	161	75	305																125a		33		
CAROTENOIDS (*mmg./100 ml.*)	59a	9	85			132a	26	38	23	63	97	45	39								74b		20		
	84	21	114	22	559						132a	265	25	2	77						125a		30		
	132a	24	137	41	385																182	4	66	42	101
VITAMIN D (*U.S.P./100 ml.*)											81	1	0.42								11			0.33	4.63
											125a			0.4	10						125a			0.5	4.0
											155	21	+	0	4										
VITAMIN E (*mg./100 ml.*)	148c	6	1.48	0.25	2.9	1 (2–3 wks. postp.)			2.6	3.3	1		0.94								1		0.06		
	156a,b*	15	1.09	0.13	3.6	148c	9	1.32	0.48	3.0	148c	5	0.90	0.78	1.14										
											156a, b	4	0.14	0.11	0.15										
VITAMIN K (*DAM-GLAVIND UNITS/100 ml.*)											40b		50	0	200						40b		200	0	400
											100		2								100		0.5		
VITAMINS, Water-soluble																									
ASCORBIC ACID (*mg./100 ml.*)	59a	10	3.9			99	15	4.6	2.7	6.6	31	7	3.5	2.1	6.0	31	5	0.9	0.7	1.1	31	7	0.7	0.2	1.1
	84	24	1.4	0.4	4.8	132a	20	7.1	4.5	9.0	36			2.5	3.6	90d	38	1.7	0.0+	3.2	90f	704	1.9	1.0	3.1
	99	16	4.1	1.7	7.2	176			5.5	5.9	74a	1500	3.9			167	266	1.2			117	6	2.2	1.9	2.4
	132a	17	7.2	4.7	10.4	180		6.2			80		5.6	2.7	8.5						161	180	1.35	0.74	2.32
	176			2.6	6.3	224b	160	3.9			99	13	4.6	2.6	6.1						220	50	2.6		
	180		5.6								132a	233	5.2	0.0	11.2										
	224b	43	3.9								224b	261	3.7	0.4	7.7										
BIOTIN, TOTAL (*mmg./100 ml.*)	132a	20	0.1	0.0+	0.3	132a	35	0.4	0.0+	1.8	132a	266	0.8	+	4.2	222	4	6.3	4.7	8.3	89b	10	4.7	3.2	8.4
											222	8	0.1	0.1	0.5						125b	11	2.2	1.4	2.9
																					137	135	2.0	0.2	5.9
																					192	29		1.7	6.2
																					222	30	5.0	1.6	11.0
CHOLINE, TOTAL (*mg./100 ml.*)											132a	29	9	5	14						58	6	15†	14†	15†
																					89b	10	15	13	17
																					105			16	28
																					132b	25	10	4	16
CHOLINE, FREE (*mg./100 ml.*)											132a	3	2	2	2						132a	21	4	2	7

---

* 1–7 days.

† Data presented as choline chloride.

TABLE 1—(*Concluded*)

	HUMAN COLOSTRUM, 1–5 DAYS					TRANSITIONAL MILK, 6–10 DAYS					MATURE HUMAN MILK					MATURE GOAT MILK					MATURE COW MILK				
	Ref. no.	No. detm.	Mean	Min.	Max.	Ref. no.	No. detm.	Mean	Min.	Max.	Ref. no.	No. detm.	Mean	Min.	Max.	Ref. no.	No. detm.	Mean	Min.	Max.	Ref. no.	No. detm.	Mean	Min.	Max.
Vitamins—(*Continued*)																									
VITAMINS, Water-soluble—(*Cont.*)																									
FOLIC ACID (*mmg./100 ml.*)											132a	22	0.22	0.14	0.36	222*	4	<3	<1	<3	132b	32	0.290	0.112	0.670
											222*	7	45	33	50						222*	15	5	1	8
INOSITOL, TOTAL (*mg./100 ml.*)											132a	7	45	39	56	222	4	21	14	26	132b	48	8	6	12
											222	9	33	19	50						222	30	18	3	39
INOSITOL, FREE (*mg./100 ml.*)											132a	5	44	39	52						132b	27	6	4	9
NICOTINIC ACID (*mmg./100 ml.*)	84			<10	80	132a	34	175	60	360	132a	268	183	66	330	90e	18	296			89b	31	91	74	114
	132a	29	75	50	145						148b		174	128	336	222	4	250	200	320	90b	15	110		
											222	9	160	120	220						125b	11	74	50	86
																					130	10	100	80	150
																					137	144	66	21	125
																					151	32	91		
																					192	29	80		
																					222	26	66	19	120
PANTOTHENIC ACID (*mmg./100 ml.*)	132a	29	183	29	302	132a	33	288	135	412	132a	269	246	86	584	90e	18	338			89b	23	310	190	420
											222	9	160	80	300	222	4	240	130	320	90b	15	366		
																					125b	11	340	220	550
																					137	72	361	155	568
																					151	32	367		
																					192	29	420		
																					222	30	290	170	460
PYRIDOXINE (*mmg./100 ml.*)											132a	3	18	10	22	222	4	7	4	13	89a	20	66	47	95
											222	9	4	2	9						125a		67		
																					132b	3	51	40	63
																					222	23	6	3	11

RIBOFLAVIN (mmg./100 ml.)	59a	9	32.0			132a	35	36.9	27.5	49.0	114	6	60	40	70	90d	30	117	76	235	41		177	164	201
	84			<25	50						132a	272	37.3	19.8	79.0	102			130	650	60	5	21.3	20.0	24.0
	132a	25	30.2	12.0	45.3						148a			16	52	222	4	110	89	120	78	400		60	342
											159			20.1	32.4						90a	37	138	108	189
											199	43	52.4	12.6	100.0						102	175	177		
											222	7	38	33	44						114	3	150	140	180
																					120b	12	210		
																					125a		200		
																					130	10	231		
																					151	32	177		
																					222	28	95	53	160
RIBOFLAVIN, FREE (mmg./100 ml.)	132a	19	19.0	7.7	27.0	132a	33	24.0	16.6	40.8	132a	256	24.2	10.5	61.8										
THIAMINE, TOTAL (mmg./100 ml.)	59a	8	35			110	48		0	9	112	24		1	29	90e	18	47			60	5	57	41	65
	84	19	19	4	82	112	26		5	26	132a	277	14	8	23	94	10	58	47	68	75	28	40		
	110	15		0.5	3	132a	35	6	2	10	141	2	22	11	32	222	4	39	32	48	90a	37	33	27	28
	112	47		0.5	27						148a			4	19						110			35	48
	132a	25	2	1	3						187	80	13	5	19						125a		38		
											199	44	18	6	31						130	10	45		
											222	8	9	<1	23						151	25	38		
																					222	8	44	31	71
THIAMINE, FREE (mmg./100 ml.)	132a	19	0.4	0.1	0.9	132a	35	0.8	0.2	1.9	132a	258	5.3	1.2	15.8	94	10	8.6	4.2	22.8	75	28	23		
											148a			2.4	9.6										
											187	61	4.3	1.3	12.4										
											209			1.7	16.7										

---

* In micrograms of material of 40,000 potency.

TABLE 2

SOME PROPERTIES AND COMPONENTS OF COW COLOSTRUM AT INTERVALS FOLLOWING PARTURITION (57)

TIME AFTER CALVING	ACIDITY*	SPECIFIC GRAVITY	FREEZING POINT, °C.	GRAMS PER 100 GM. OF SECRETION							
				Chlorides	Total protein†	Casein	Albumin‡	Ash	Dry matter	Sugar	Fat
At once§	18.4	1.0670	−0.605	0.1525	17.57	5.08	11.34	1.01	26.99	2.19	5.10
6 hours§	14.4	1.0437	−0.555	0.1631	10.00	3.51	6.30	0.91	20.46	2.71	6.85
12 hours§	11.2	1.0368	−0.566	0.1560	6.05	3.00	2.96	0.89	14.53	3.71	3.80
24 hours§	10.8	1.0343	−0.575	0.1560	4.52	2.76	1.48	0.86	12.77	3.98	3.40
30 hours§	9.8	1.0318	−0.570	0.1524	4.01	2.56	1.20	0.83	13.63	4.27	4.90
36 hours§	10.0	1.0320	−0.570	0.1595	3.98	2.77	1.03	0.84	12.22	3.97	3.55
48 hours§	9.6	1.0319	−0.580	0.1489	3.74	2.63	0.99	0.83	11.46	3.97	2.80
72 hours§	10.0	1.0331	−0.575	0.1365	3.86	2.70	0.97	0.84	11.86	4.37	3.10
96 hours	9.2	1.0335	−0.555	0.1347	3.76	2.68	0.82	0.83	11.85	4.72	2.80
5 days	8.5	1.0334	−0.575	0.1312	3.86	2.68	0.87	0.85	12.67	4.76	3.75
7 days	9.0	1.0320	−0.570	0.1134	3.31	2.42	0.69	0.84	12.13	4.96	3.45

* Acidity was determined by the Soxhlet-Henkel method which consists of titrating 25 ml. of milk with 0.25 Normal sodium hydroxide to a slight rose color with 2 ml. of two per cent solution of phenolphthalein in alcohol as an indicator. One degree of acidity equals 1 ml. 0.25 Normal sodium hydroxide per 100 ml. milk.

† Nitrogen × 6.37.

‡ The figures for "albumin" actually represent albumin and globulin.

§ Only secretion obtained at these intervals after calving coagulates on boiling.

TABLE 3

THE VITAMIN CONTENT OF COWS' COLOSTRUM AND MILK DURING EARLY LACTATION

Values in milligrams per 100 ml.

DAYS AFTER PARTURITION	VITAMIN A	CAROTENE	THIAMINE	RIBOFLAVIN	PANTOTHENIC ACID	NIACIN
0	.240	.47	.058	.59	.17	Colostrum
1	.129	.26	.059	.33	.32	.096
2	.073	.13	.059	.24	.40	
3	.048	.10	.059	.22	.42	
4	.037	.06	.058	.20	.40	
5	.035	.05	.059	.20	.41	Milk
10	.040	.05	....	.19	...	.091
30	....	.04	.038	.18	.38	

TABLE 4
COMPOSITION OF PROTEINS IN MATURE HUMAN, GOAT AND COW MILKS

VALUES IN GRAMS PER 100 GM. OF PROTEIN	MATURE MILKS		
	Human	Goat	Cow
CASEIN COMPONENTS			
ASH		0.36	0.06
ELEMENTAL COMPOSITION			
CARBON	52.65	52.50	53.20
HYDROGEN	7.21	7.16	7.02
NITROGEN	14.89	15.67	15.55
OXYGEN	23.11	23.25	22.56
PHOSPHORUS	0.57	0.71	0.82
SULFUR	0.88	0.71	0.76
SULFUR DISTRIBUTION			
CYSTINE SULFUR	0.195		0.069
METHIONINE SULFUR	0.471		0.666
CYSTINE PLUS METHIONINE SULFUR	0.666		0.735
AMINO ACID DISTRIBUTION			
Dispensable			
ALANINE	2.0	1.8	2.3
ASPARTIC ACID	4.6	1.7	5.8
CYSTINE	0.64	tr	0.34
GLUTAMIC ACID	20.9	12.1	21.7
GLYCINE	0		0.4
PROLINE	8.9	6.9	9.8
SERINE	5.4	0.7	5.4
TYROSINE	5.69	4.87	5.96
Indispensable			
ARGININE	3.43	2.66	3.77
HISTIDINE	1.77	1.85	2.25
ISOLEUCINE	6.3		6.1
LEUCINE	12.2	11.4	10.8
LYSINE	5.4	3.7	6.8
METHIONINE	2.40		2.88
PHENYLALANINE	5.8	2.0	5.5
THREONINE	4.5		4.35
TRYPTOPHANE	1.41	1.37	1.22
VALINE	5.0	6.0	6.6
WHEY COMPONENTS			
SULFUR DISTRIBUTION			
TOTAL SULFUR	1.47		1.39
CYSTINE SULFUR	0.825		0.662
METHIONINE SULFUR	0.410		0.586
CYSTINE PLUS METHIONINE SULFUR	1.235		1.248
AMINO ACID DISTRIBUTION			
Dispensable			
CYSTINE	3.62		2.90
TYROSINE	4.84		4.17

TABLE 4—(*Continued*)

VALUES IN GRAMS PER 100 GM. OF PROTEIN	MATURE MILKS		
	Human	Goat	Cow
WHEY COMPONENTS—Continued			
SULFUR DISTRIBUTION—*Continued*			
Indispensable			
ARGININE	5.10		3.74
HISTIDINE	1.40		1.62
LYSINE	6.18		7.09
METHIONINE	1.66		2.51
TRYPROPHANE	2.40		1.86
LACTALBUMIN COMPONENTS			
NITROGEN	14.94		14.92
AMINO ACID DISTRIBUTION			
Dispensable			
ALANINE	2.5		2.6
ASPARTIC ACID	9.3		9.6
CYSTINE	3.8	3.7	3.1
GLUTAMIC ACID	12.5		15.2
GLYCINE	0		0
PROLINE	3.5		4.0
SERINE	4.2		4.0
TYROSINE	4.5	4.2	4.0
Indispensable			
ARGININE	5.0	2.1	3.4
HISTIDINE	1.5	2.6	1.6
ISOLEUCINE	4.3		5.1
LEUCINE	16.7		14.1
LYSINE	6.6		7.3
METHIONINE	1.7		2.4
PHENYLALANINE	4.8		4.1
THREONINE	4.0		5.0
TRYPTOPHANE	2.3	2.4	2.1
VALINE	4.1		5.0
BETA-LACTOGLOBULIN COMPONENTS			
ELEMENTAL COMPOSITION			
CARBON			53.39
HYDROGEN			7.22
NITROGEN			15.60
SULFUR			1.60
OXYGEN			22.19
SULFUR DISTRIBUTION			
CYSTINE SULFUR PLUS CYSTEINE SULFUR			0.905
METHIONINE SULFUR			0.692
SULFATE SULFUR			0
NITROGEN DISTRIBUTION			
AMIDE NITROGEN			1.076
AMIDE AMMONIA			1.3
INDOLE NITROGEN			0.133

TABLE 4—(*Continued*)

VALUES IN GRAMS PER 100 GM. OF PROTEIN	MATURE MILKS		
	Human	Goat	Cow
BETA-LACTOGLOBULIN COMPONENTS—Continued			
NITROGEN DISTRIBUTION—*Continued*			
GUANADINO NITROGEN			0.695
IMIDAZOLE NITROGEN			0.285
e-AMINO NITROGEN			1.092
NON-ALPHA NITROGEN			3.28
ALPHA NITROGEN			12.319
FREE AMINO NITROGEN			1.247
FREE ALPHA AMINO NITROGEN			0.155
PEPTIDE NITROGEN			12.164
AMINO ACID DISTRIBUTION			
Dispensable			
ALANINE			6.8
ASPARTIC ACID			11.0
CYSTEINE			1.1
CYSTINE		1.8	4.0
HALF CYSTINE			2.3
GLUTAMIC ACID, TOTAL			19.8
GLUTAMIC ACID, FREE			8.2
GLUTAMINE			11.2
GLYCINE			1.5
PROLINE			4.7
SERINE			4.3
TYROSINE		4.0	3.7
Indispensable			
ARGININE		1.7	2.9
HISTIDINE		2.3	1.6
ISOLEUCINE			6.8
LEUCINE			15.5
LYSINE			11.3
METHIONINE			3.2
PHENYLALANINE			3.7
THREONINE			5.3
TRYPTOPHANE		1.8	1.9
VALINE			5.8

TABLE 5

REPRESENTATIVE SUMMARY VALUES FOR THE PROPERTIES AND THE COMPOSITION OF HUMAN COLOSTRUM, TRANSITIONAL AND MATURE MILK, MATURE GOAT MILK AND MATURE COW MILK

	1–5 DAYS	5–10 DAYS	MATURE MILK		
			Human	Goat	Cow
PHYSICAL PROPERTIES					
ELECTRICAL CONDUCTIVITY					0.0086
GOLD NUMBER	2370	792			
FREEZING POINT °C					0.546
INDEX OF REFRACTION (at 40°C.)			1.4570		1.4001
OSMOTIC PRESSURE					196
pH VALUE				6.37	6.50
REFRACTIVE CONSTANT					0.2070
SPECIFIC GRAVITY	1.034	1.035	1.031	1.033	1.033
SURFACE TENSION (dynes/sq. cm.)				52.0	52.8
VISCOSITY (at 15°C.)					1.75
FAT CHARACTERISTICS					
FAT MELTING POINT °C		32	31		
HEHNER NUMBER				88.2	89.2
HUBL NUMBER					35.2
IODINE NUMBER	(early lactation 60.4)		61.6	28.8	38.4
KIRSCHNER VALUE	(early lactation 0.6)		0.5	17.8	24.0
POLENSKE NUMBER	(early lactation 0.6)		1.2	7.7	1.5
REICHERT-MEISEL NUMBER	(early lactation 1.8)		0.8	27.4	28.8
SAPONIFICATION NUMBER	(early lactation 205.1)		204.7	235.9	248.0
THIOCYANOGEN NUMBER				27	34
SOLUBLE ACIDS				4.5	4.2
CHEMICAL COMPONENTS					
CITRIC ACID mg./100 ml.				151	217
TITRABLE ACIDITY, % LACTIC ACID				0.199	0.144
INDICAN mmg.*/100 ml.			30	192	124
WATER, gm./100 ml. whole milk	87	86	88	86	87
ENERGY, CAL./100 ml. whole milk	58	74	71	78	69
TOTAL SOLIDS, gm./100 ml. whole milk	12.8	13.6	12.4	13.6	12.8
ASH, gm./100 ml. whole milk	0.33	0.24	0.21	0.77	0.71
per cent total solids	2.6	1.8	1.7	5.7	5.5
FAT, gm./100 ml. whole milk	2.9	3.6	3.8	4.1	3.8
per cent total solids	22.6	26.5	30.6	30.1	29.7
LACTOSE, gm./100 ml. whole milk	5.3	6.6	7.0	4.7	4.8
per cent total solids	41.4	48.5	56.4	34.6	37.5

* mmg. = micrograms.

TABLE 5—(*Continued*)

	1-5 DAYS	5-10 DAYS	MATURE MILK		
			Human	Goat	Cow
CHEMICAL COMPONENTS—Continued					
TOTAL SOLIDS—*Continued*					
PROTEIN, gm./100 ml.					
whole milk	2.7	1.6	1.2	3.4	3.3
per cent total solids	21.1	11.8	9.7	25.0	25.8
ASH, MAJOR COMPONENTS					
CALCIUM, mg./100 ml.					
whole milk	31	34	34	130	126
per cent total ash	9	14	16	17	18
CHLORINE, mg./100 ml.					
whole milk	91	54	43	159	100
per cent total ash	28	22	20	21	14
MAGNESIUM, mg./100 ml.					
whole milk	4	4	4	16	13
per cent total ash	1	2	2	2	2
PHOSPHORUS, mg./100 ml.					
whole milk	14	17	16	106	99
per cent total ash	4	7	8	14	14
POTASSIUM, mg./100 ml.					
whole milk	74	64	55	181	138
per cent total ash	22	27	26	24	19
SODIUM, mg./100 ml. whole milk	48	29	15	41	58
per cent total ash	14	12	7	5	8
SULFUR, mg./100 ml. whole milk	22	20	14	16	30
per cent total ash	7	8	7	2	4
ASH, MINOR COMPONENTS (Milligrams per 100 ml. whole milk)					
ALUMINUM			tr	tr	tr
BARIUM			tr	tr	tr
BORON			tr	0.0177	0.0156
BROMINE			0.912		0.021
CHROMIUM			tr	tr	tr
COBALT					0.00006
COPPER	0.06		0.04	0.04	0.03
FLUORINE					0.016
IODINE	0.012	0.002	0.011		0.021
			(skimmed milk)		
IRON	0.12		0.21	0.05	0.13
LEAD			0.016	tr	tr
LITHIUM			tr	tr	tr
MANGANESE	tr		0.0007	0.008	0.002
MOLYBDENUM			tr	0	tr
NICKEL					0.013
RUBIDIUM			1		tr

TABLE 5—(*Continued*)

	1–5 DAYS	5–10 DAYS	MATURE MILK		
			Human	Goat	Cow
CHEMICAL COMPONENTS—Continued					
ASH; MINOR—*Continued*					
RUTHENIUM					tr
SILICON					tr
SILVER			tr	tr	tr
STRONTIUM			tr	tr	tr
TIN					0
TITANIUM			tr	tr	tr
VANADIUM			tr	tr	tr
ZINC	0.65	1.15	0.66		0.35
SALTS					
(Grams per 100 ml. whole milk)			0.313	0.939	0.901
DI-CALCIUM PHOSPHATE			0.000	0.092	0.175
TRI-CALCIUM PHOSPHATE			0.000	0.062	0.000
MONO-MAGNESIUM PHOSPHATE			0.027	0.000	0.103
DI-MAGNESIUM PHOSPHATE			0.000	0.068	0.000
TRI-MAGNESIUM PHOSPHATE			0.000	0.024	0.000
MONO-POTASSIUM PHOSPHATE			0.069	0.073	0.000
DI-POTASSIUM PHOSPHATE			0.000	0.000	0.230
POTASSIUM CITRATE			0.103	0.250	0.052
SODIUM CITRATE			0.055	0.000	0.222
POTASSIUM CHLORIDE			0.000	0.160	0.000
SODIUM CHLORIDE			0.000	0.095	0.000
CALCIUM CHLORIDE			0.059	0.115	0.119
ANION-CATION RELATIONSHIPS (ACID-BASE EQUIVALENTS)					
(Milliequivalents per 100 ml. whole milk)					
TOTAL ELECTROPOSITIVE IONS (CATIONS, BASE)	5.85	4.93	4.09	14.22	13.41
CALCIUM	1.54	1.70	1.70	6.49	6.29
per cent total cations	26	34	42	46	47
MAGNESIUM	0.33	0.33	0.33	1.32	1.07
per cent total cations	6	7	8	9	8
POTASSIUM (184)	1.89	1.64	1.41	4.63	3.53
per cent total cations	32	33	34	33	26

	1-5 DAYS	5-10 DAYS	MATURE MILK		
			Human	Goat	Cow
CHEMICAL COMPONENTS—Continued					
ANION-CATION RELATIONSHIPS—*Continued*					
SODIUM	2.09	1.26	0.65	1.78	2.52
per cent total cations	36	26	16	12	19
TOTAL ELECTRONEGATIVE IONS (ANIONS, ACID)	4.75	3.76	3.01	11.64	10.44
CHLORINE	2.57	1.52	1.21	4.48	2.82
per cent total anions	54	41	40	38	27
PHOSPHORUS	0.81	0.99	0.93	6.16	5.75
per cent total anions	17	26	31	53	55
SULFUR	1.37	1.25	0.87	1.00	1.87
per cent total anions	29	33	29	9	18
ALKALINE-ASH VALUE (EXCESS OF CATIONS OVER ANIONS)	1.10	1.17	1.08	2.58	2.97
ENERGY DISTRIBUTION (Calories per 100 ml. whole milk)					
ENERGY VALUES REPORTED	58	74	71	78	69
CALCULATED ENERGY					
Fat (gm. × 9.25†)	27	33	35	38	35
Lactose (gm. × 3.95†)	21	26	28	19	19
Protein (gm. × 5.65†)	15	9	7	19	19
TOTAL	63	68	70	76	73
Percentage from FAT	43	49	50	50	48
Percentage from LACTOSE	33	38	40	25	26
Percentage from PROTEIN	24	13	10	25	26
FAT DISTRIBUTION, grams per 100 ml. milk					
FAT, TOTAL	2.9	3.6	3.8	4.1	3.8
LIPOID PHOSPHORUS	0.002	0.003	0.004	0.004	0.004
TOTAL CHOLESTEROL	0.027	0.028	0.020	0.024	0.014
FREE CHOLESTEROL					0.012
LECITHIN			0.078		0.057
FATTY ACID DISTRIBUTION) (Grams per 100 ml. whole milk)					
Saturated Fatty Acids					
BUTYRIC ACID	0.2		0.4	2.6	3.1

---

† Atwater factors for heat of combustion of fat and protein in "dairy products" and for "sugar" taken from Maynard, L. A., The Atwater System of Calculating the Calorie Value of Diets, J. Nutrition *28:* 443–452, 1944. For "available" energy or "physiological fuel values," the factors 8.80 for fat, 3.85 for lactose, and 4.25 for protein should be substituted for the heat of combustion values and the energy distribution recalculated accordingly.

TABLE 5—(*Continued*)

	1–5 DAYS	5–10 DAYS	MATURE MILK		
			Human	Goat	Cow
CHEMICAL COMPONENTS—Continued					
FATTY ACID DISTRIBUTION—*Continued*					
CAPROIC ACID	0.1		0.1	2.3	1.0
CAPRYLIC ACID	0.4		0.3	2.7	1.2
CAPRIC ACID	2.2	1.8‡	1.7	8.4	2.6
LAURIC ACID	1.8	5.6‡	5.8	4.5	2.2
MYRISTIC ACID	3.8	9.4‡	8.6	11.1	10.5
PALMITIC ACID	26.2	23.6‡	22.6	28.9	26.3
STEARIC ACID	8.8	7.8‡	7.7	7.8	13.2
as ARACHIDIC ACID	3.8	1.4‡	1.0	0.4	1.2
Unsaturated Fatty Acids					
DECENOIC ACID	0.2	tr‡	0.1	0.2	0.2
DODECENOIC ACID	0.1	0.1‡	0.1	0.3	0.2
TETRADECENOIC ACID	0.2	0.8‡	0.6	0.5	1.1
HEXADECENOIC ACID	2.4	3.2‡	2.9	2.5	3.1
OLEIC ACID	36.6	34.6‡	36.4	27.0	32.2
OCTADECADIENOIC ACID	6.8	7.1‡	8.3	2.6	2.8
OCTADECATRIENOIC ACID	0.3		0.4		
as EICOSADIENOIC ACID	4.6		2.4		
EICOSATETRAENOIC ACID	1.7		0.9		
C 20–22 ACID	10.2	4.6‡	4.2	0.4	1.0
OCTADECATETRENOIC ACID			0.2		
ARACHIDONIC ACID			0.8	1.5	1.0
LINOLEIC ACID					0.5
PHOSPHORUS DISTRIBUTION mg./100 ml. wholemilk					
PHOSPHORUS, ACID SOLUBLE, TOTAL				86	82
PHOSPHORUS, ACID SOLUBLE, INORGANIC					68
PHOSPHORUS, ACID SOLUBLE, ESTER, Organically bound					10.2
PHOSPHORUS, ACID INSOLUBLE, TOTAL					26.0
PHOSPHORUS, RIBONUCLEIC ACID			0.2	2.3	1.6

‡ 1st 3 weeks.

TABLE 5—(*Continued*)

	1–5 DAYS	5–10 DAYS	MATURE MILK		
			Human	Goat	Cow
CHEMICAL COMPONENTS—Continued					
PHOSPHORUS DISTRIBUTION—*Continued*					
PHOSPHORUS, INORGANIC, TOTAL			5.3	79	80
PHOSPHORUS, ORGANIC, TOTAL				14.4	
NITROGEN DISTRIBUTION (Grams per 100 ml. whole milk)					
TOTAL NITROGEN	0.515	0.317	0.227	0.574	0.551
PROTEIN NITROGEN	0.424	0.251	0.188	0.534	0.518
per cent total nitrogen	82	79	83	93	94
NON-PROTEIN NITROGEN	0.091	0.066	0.039	0.040	0.033
per cent total nitrogen	18	21	17	7	6
PROTEIN DISTRIBUTION (Grams per 100 ml. whole milk)					
TOTAL PROTEIN					
CASEIN	1.2	0.7	0.4	2.5	2.8
per cent total protein	44	44	33	74	85
LACTALBUMIN		0.8	0.3	0.4	0.4
per cent total protein		50	25	12	12
LACTOGLOBULIN		0.5	0.2	0.3	0.2
per cent total protein		31	17	9	6
WHEY PROTEIN	1.7		0.6	1.1	0.6
per cent total protein	63		50	32	18
PROTEIN NITROGEN DISTRIBUTION (Milligrams per 100 ml. whole milk)					
TOTAL PROTEIN NITROGEN					
CASEIN NITROGEN	188	110	63	392	440
per cent total protein nitrogen	44	44	34	73	85
LACTALBUMIN NITROGEN		126	47	63	63
per cent total protein nitrogen		50	25	12	12
LACTOGLOBULIN NITROGEN		78	31	47	31
per cent total protein nitrogen		31	16	9	6
WHEY NITROGEN	267		94	173	94
per cent total protein nitrogen	63		50	32	18

TABLE 5—(*Continued*)

	1–5 DAYS	5–10 DAYS	MATURE MILK		
			Human	Goat	Cow
CHEMICAL COMPONENTS—Continued					
NON-PROTEIN NITROGEN COMPONENTS					
(Milligrams per 100 ml. whole milk)					
CREATINE			3.3		2.4
CREATININE			2.2		1.0
UREA		23.3	32.2		19.5
URIC ACID			4.6		1.5
NON-PROTEIN NITROGEN DISTRIBUTION					
(Milligrams per 100 ml. whole milk)					
AMINO ACID NITROGEN		4	6		4
per cent non-protein nitrogen		6.1	15.4		12.1
CREATINE NITROGEN (Factor = 3.1)			1.1		0.8
per cent non-protein nitrogen			2.8		2.4
CREATININE NITROGEN (Factor = 2.7)			0.8		0.4
per cent non-protein nitrogen			2.0		1.2
UREA NITROGEN (Factor = 2.1)		11.1	15.3		9.3
per cent non-protein nitrogen		16.8	39.2		28.2
URIC ACID NITROGEN (Factor = 3.0)			1.5		0.5
per cent non-protein nitrogen			3.8		1.5
TOTAL AMINO ACID DISTRIBUTION					
(Milligrams per 100 ml. whole milk)					
Dispensable Amino Acids					
ALANINE			35		75
per cent total protein			2.9		2.3
per cent from casein			22.8		85.3
ASPARTIC ACID			116		166
per cent total protein			9.7		5.0
per cent from casein			15.5		97.6
CYSTINE		48	29		28
per cent total protein		3.0	2.4		0.8
per cent from casein			6.9		35.7

TABLE 5—(*Continued*)

	1-5 DAYS	5-10 DAYS	MATURE MILK		
			Human	Goat	Cow
CHEMICAL COMPONENTS—Continued					
TOTAL AMINO ACID DISTRIBUTION—*Continued*					
GLUTAMIC ACID			230		680
per cent total protein			19.2		20.6
per cent from casein			36.5		89.4
GLYCINE			0		11
per cent total protein			0.0		0.3
per cent from casein					100
PROLINE			80		250
per cent total protein			6.7		7.6
per cent from casein			45.0		109.6
SERINE			69		160
per cent total protein			5.7		4.8
per cent from casein			31.9		94.4
TYROSINE		105	61		191
per cent total protein		6.6	5.1		5.8
per cent from casein			37.7		87.4
Indispensable Amino Acids					
ARGININE	74	135	50		122
per cent total protein	2.7	8.4	4.2		3.7
per cent from casein			28.0		86.9
HISTIDINE	41	44	23		72
per cent total protein	1.5	2.8	1.9		2.2
per cent from casein			30.4		87.5
ISOLEUCINE	101	101	80		221
per cent total protein	3.7	6.3	6.7		6.7
per cent from casein			31.2		77.4
LEUCINE	166	152	154		398
per cent total protein	6.1	9.5	12.8		12.1
per cent from casein			31.8		75.9
LYSINE	118	118	75		243
per cent total protein	4.4	7.4	6.2		7.4
per cent from casein			29.3		78.2
METHIONINE	25	30	22		93
per cent total protein	0.9	1.9	1.8		2.8
per cent from casein			45.4		87.1
PHENYLALANINE	70	88	64		181
per cent total protein	2.6	5.5	5.3		5.5
per cent frm casein			35.9		85.1
THREONINE	85	88	59		152
per cent total protein	3.1	5.5	4.9		4.6
per cent from casein			30.5		80.3
TRYPTOPHANE	32	34	22		46
per cent total protein	1.2	2.1	1.8		1.4
per cent from casein			27.3		73.9
VALINE	117	120	87		233
per cent total protein	4.3	7.5	7.2		7.1
per cent from casein			23.0		79.4

TABLE 5—(*Concluded*)

	1-5 DAYS	5-10 DAYS	MATURE MILK		
			Human	Goat	Cow
VITAMINS					
(Values per 100 ml. whole milk)					
Fat-Soluble Vitamins					
VITAMIN A, mmg.	89	88	54		37
CAROTENOIDS, mmg.	112	38	32		39
VITAMIN D, U.S.P. UNITS			0.42		
VITAMIN E, mg.	1.28	1.32	0.66		0.06
VITAMIN K, Dam-Glavind Units			26		100
Water-Soluble Vitamins					
ASCORBIC ACID, mg.	4.4	5.4	4.4	1.3	1.8
BIOTIN, TOTAL, mmg.	0.1	0.4	0.4	6.3	3.5
CHOLINE, mg.			9		13
CHOLINE, FREE, mg.			2		4
FOLIC ACID, mmg.			0.22		0.29
INOSITOL, TOTAL, mg.			39	21	13
INOSITOL, FREE, mg.			44		6
NICOTINIC ACID, mmg.	75	175	172	273	85
PANTOTHENIC ACID, mmg.	183	288	203	289	350
PYRIDOXINE, mmg.			11	7	48
RIBOFLAVIN, TOTAL, mmg.	31.1	36.9	46.9	114	158
RIBOFLAVIN, FREE, mmg.	19.0	24.0	24.2		
THIAMINE, TOTAL, mmg.	19	6	15	48	42
THIAMINE, FREE, mmg.	0.4	0.8	4.8	8.6	23

The National Research Council

Membership and Organization.—The National Research Council is a cooperative organization of scientific men of America, including also a representation of men of affairs interested in engineering and industry and in the basic sciences upon which the applications of science depend. Its membership is largely composed of accredited representatives of about eighty-five national scientific and technical societies. Its essential purpose is the promotion of scientific research and of the application and dissemination of scientific knowledge for the benefit of the national strength and well-being.

The Council was established at the request of the President of the United States, by the National Academy of Sciences, under its Congressional charter to coordinate the research facilities of the country for work on military problems involving scientific knowledge. In 1918, by Executive Order, it was reorganized as a permanent body for the general encouragement of scientific research.

Q11.N292.no.111 - 119.

DATE DUE

[redacted]			
[redacted]			

Q11.N292.no.111 - 119.
National Research Council.
Bulletin.

DATE DUE	BORROWER'S NAME	ROOM NUMBER
~~7/11/68~~	~~Atomic Energy Commission~~ ~~Bethesda Tech. Library~~ ~~Washington, D.C. STOP 4~~ ~~Attn: Devine 119 x-7400~~	
	~~[illegible] 10/21/68~~	

NATIONAL ACADEMIES LIBRARY
12020